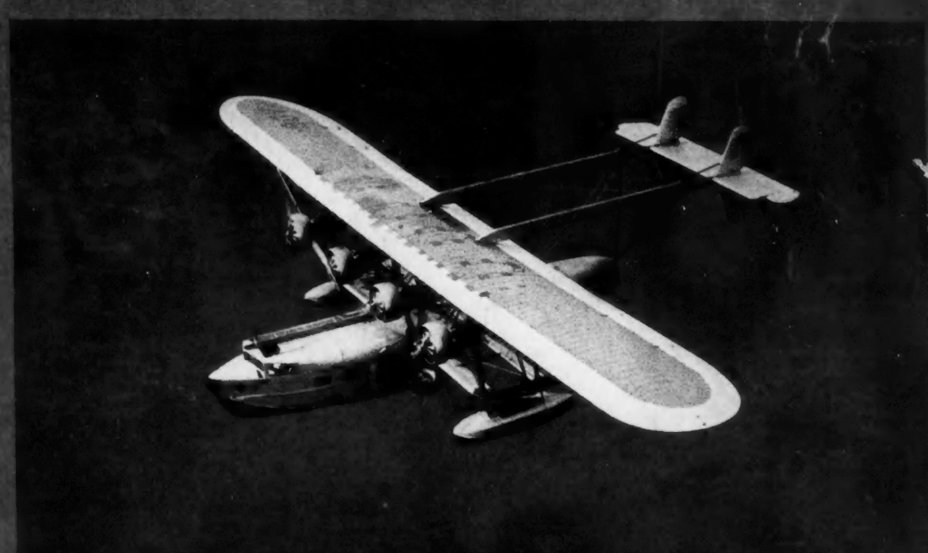
# S·A·E JOURNAL



APRIL 1932

# S·A·E· JOURNAL

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Note: Page numbers above that are preceded by (T) refer to the Transactions section (between pp. 28 and 29 of the advertising and news section) containing papers and discussion that will be embodied in the volume of S.A.E. Transactions for 1932, to be issued early in 1933.

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The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

S·A·E JOURNAL

# Three Days of Excellent Aeronautic Papers

## *Detroit Meeting Opens with a Student Session on April 5 and Ends with Aviation Dinner April 7*

AGAIN taking its place among the major events during the National Aircraft Show in Detroit, the semi-annual Aeronautic Meeting of the Society will be held on April 5, 6 and 7 in the Hotel Statler, Detroit.

Since the coordination of the many former aircraft shows into one annual National exhibition, this affair has been the focal point of the industry during the first week in April. The concentration of engineers and executives in the aircraft industry and the allied aeronautic industries makes possible the discussion of engineering problems as the occasion brings together in one city the manufacturers, the designers and the operators for mutual consideration of the technical development of aircraft and aircraft engines and engineering phases of their maintenance and repair.

### Detroit Section Student Session

The opening session, to be held in the Grand Ballroom of the Statler, will be under the auspices of the Detroit Section of the Society and will be in the nature of a student meeting, for which the Section has become well known in university circles. Students and members attending this session are offered the unusual opportunity to hear two of the best-known men in aviation: Charles S. ("Casey") Jones, vice-president of the Curtiss-Wright Corp., and Brigadier-Gen. William Mitchell, U.S.A., retired. Both of these men have been associated with the industry since its inception, and each has attained to eminence in his own particular field. "Casey" has become familiar to thousands as an exponent of flying for Mr. and Mrs. John B. Public through his broadcasts over the Columbia chain. Brigadier-General Mitchell needs no introduction to anyone interested in the position that America holds in the air.

SPEAKERS AT THE DETROIT SECTION STUDENT SESSION. (LEFT) BRIGADIER-GEN. WILLIAM MITCHELL, U.S.A., RETIRED, AND (RIGHT) CHARLES S. (CASEY) JONES

The technical sessions start with the meeting at 10 a. m. on Wednesday, April 6, and will be held in the large banquet hall of the Statler. Under the chairmanship of T. P. Wright, the first session will be devoted to two important papers dealing with structures. Edward P. Warner, editor of *Aviation*, is to discuss a new method of analyzing loads on wings and their variation in different types of aircraft. His paper on The Rational Specification of Airplane Load Factors is printed in full in this number of THE JOURNAL. This paper is particularly timely in view of the interest in the subject and the work being done on load factors by the Aeronautical Chamber of Commerce with the Aeronautics Branch of the Department of Commerce.

The second paper deals with the history, theory and application of the photoelastic polariscope as a method of stress analysis. It will be given by D. L. Pellett, of the University of Cincinnati, under the title, Photoelasticity and Its Application to the Study of Indeterminate Truss Stresses.

At 2 p. m. of the same day, R. M. Hazen, assistant engineer of the American Airplane & Engine Corp., will discuss the problems encountered in the development of higher speeds, the use of re-

# Meetings Calendar

## National Meetings

**Aeronautic Meeting—April 5 to 7**

Hotel Statler, Detroit

In conjunction with the Aeronautical Chamber of Commerce of America and the Detroit Section, S.A.E.

**Summer Meeting—June 12 to 17**

White Sulphur Springs, W. Va.

**Aeronautic Meeting—Aug. 30, 31 and Sept. 1**

Hotel Statler, Cleveland

In conjunction with the Aeronautical Chamber of Commerce of America during the National Air Races

**Production Meeting—Week of Sept. 10**

Cleveland

In conjunction with the National Machine Tool Show

**Production Meeting—Oct. 3 to 10**

174th Regiment Armory, Buffalo

In cooperation with the National Metal Congress and Exposition

**Transportation Meeting—October**

Royal York Hotel, Toronto, Canada

## April Section Meetings

**Baltimore—April 14**

Speaker: Dr. Graham Edgar, Director of Research, Ethyl Gasoline Corp.

**Buffalo—No Meeting**

**Canadian—April 20**

Royal York Hotel, Toronto; Dinner 6:30 P.M.

High-Compression Engines and Fuels—Homer H. Dedo, Research Engineer, Ethyl Gasoline Corp.

**Chicago—April 5**

Hotel Sherman; Dinner 6:30 P.M.; Entertainment

Some of the Factors Controlling Engine Design—James B. Fisher, Chief Engineer, Waukesha Motor Co.

How Much More Power Can an Automotive Engine Produce?—Earl Bartholomew, Director, Engineering Laboratories, Ethyl Gasoline Corp.

**Cleveland—April 11**

Nela Park, East Cleveland; Dinner 6:30 P.M.

Visit to Nela School of Light; demonstration and exhibit by Willard C. Brown, Illuminating Engineer, General Electric Co.

State Reciprocity Regarding Automobile and Truck Fees—Col. Chalmers R. Wilson, Commissioner of Motor Vehicles, State of Ohio

**Dayton—April 19**

Engineers Club; Dinner 6:30 P.M.

Joint Meeting with Aeronautical Chamber of Commerce of America

Recent Developments in Aviation Instruments—Harold Gatty, Chief Navigation Engineer, Army Air Corps, and Capt. A. F. Hegenberger, Army Air Corps

Engineering and Its Relation to Aviation—By a representative of the Aeronautical Chamber of Commerce

**Detroit—April 5 to 7**

Hotel Statler; 8 P.M., April 5

Student Meeting and cooperation in the Aeronautic Meeting of the Society

**Indiana—April 21**

Purdue University Campus, Lafayette, Ind.; 2 to 10 P.M.; Dinner 6:30 P.M., Memorial Union Building

Demonstrations and Tests:

The "Shake Table" and Its Effects on Human Beings; Forces and Frequencies of Vibration in Three Directions in Automobiles; Testing a Tractor; Testing a Truck; Moments of Inertia and Radii of Gyration of Automobiles; Tests of Fuels; A New-Type Torsiograph; Effects of Cooling Pistons

Addresses:

The Place of Research in Colleges—R. A. Potter, Dean of Engineering, Purdue Uuiversity

Making Research Pay—H. L. Horning, President, Waukesha Motor Co.

**Metropolitan—April 21**

A.W.A. Clubhouse, 357 West 57th Street, New York City; Dinner 6:30 P.M.

The Bus and Truck of the Future—B. B. Bachman and other well-known engineers

**Milwaukee—April 6**

Milwaukee Athletic Club; Dinner 6:30 P.M.; Entertainment.

Automotive Equipment Employed on Mississippi Flood-Control Work—F. Carl Ruhloff, Sales Engineer, Bucyrus Erie Co.

**New England—April 20**

Walker Memorial, Massachusetts Institute of Technology, Cambridge

J. F. Winchester, Superintendent of Motor-Vehicles, Standard Oil Co. of New Jersey, will talk on transportation problems

**Northwest—April 8**

New Washington Hotel, Seattle, Wash.; Dinner 6:30 P.M.

Joint meeting with the Aeronautical Chamber of Commerce of America

Engineering and Its Relation to Aviation—P. G. Johnson, United Aircraft & Transport

C. N. Monteith, Boeing Airplane Co., will present a paper

**Pittsburgh—April 5**

Fort Pitt Hotel; Dinner 6:30 P.M.

Brake Problems—Dr. F. C. Stanley, Chief Engineer, Raybestos Division, Raybestos Manhattan, Inc.

Wheel and Brake-Drum Design—A. S. Van Haltern, Executive Engineer, Motor Wheel Corp.

Motion Pictures will be shown

**Southern California—April 9**

Alexandria Hotel, Los Angeles; Dinner 7:00 P.M.

Annual Social Affair—Dancing and Entertainment

**Syracuse—April 14**

Hotel Syracuse; 8:15 P.M.

Automobile Headlighting of 1932—W. C. Brown, Engineer, General Electric Co.

**Wichita—No Meeting**

duction gearing and the increase of brake mean effective pressure in the design of a high-speed engine. His paper, entitled Development Problems of Aircraft Engines of High Specific Output, should be of great interest in view of the work that his company has recently done in the development of its engine.

An authoritative presentation of the facts regarding the interrelated functional characteristics associated with present tendencies in engine development will be given by Oscar W. Schey, of the National Advisory Committee for Aeronautics, in a paper entitled, Scavenging a Supercharged Spark-Ignition Engine, Using Fuel Injection, by the Use of Large Valve Overlap. Charles L. Lawrance will act as chairman of this session.

Harold Gatty, navigator on the Post-Gatty round-the-world flight, who is now chief navigation engineer for the Army Air Corps, will present at the evening session on April 6, for the first time, the methods and equipment for quickly and accurately determining the position and laying the course of aircraft. In his paper, Aerial Navigation—Methods and Equipment, printed in this issue of THE JOURNAL, he deals with the methods of navigation on his round-the-world flight and also with developments in the science and instruments since that time.

In his paper, entitled Flight Control by Air Visualization, Ralph H. Upson is to describe the application of this

AUTHORS OF AERONAUTIC MEETING PAPERS AND SPEAKERS AT THE AVIATION DINNER

(1) The Hon. Clarence M. Young, Assistant Secretary of Commerce, Guest Speaker at Dinner. (2) Edward P. Warner, Author of Paper on Load Factors. (3) D. L. Pellett, Author of Paper on Photoelasticity. (4) R. M. Hazen, Author of Paper on Engine Development Problems. (5) Oscar W. Schey, Who Is To Speak on a Supercharged Spark-Ignition Fuel-Injection Engine. (6) A. E. Larsen, Who Will Describe Engineering Aspects of the Autogiro. (7) Prof. E. S. Taylor, Who Will Tell How To Balance a Four-Cylinder Engine. (8) Luther Harris, Who Deals with Maintenance from the Operator's Viewpoint. (9) John G. Lee, Who Will Discuss Maintenance as the Designer Sees It. (10) Charles L. Lawrance, First Speaker at the Dinner. (11) Harold Gatty, Navigator on the Post and Gatty Round-the-World Flight, Who Will Describe Avigation Methods and Instruments. (12) Ralph Upson, Who Will Describe a New Method of Flight Control and the Instrumentation by Which It Is Accomplished

method of flight control and the instrumentation by which it is accomplished. This paper also is published in this issue of THE JOURNAL.

William B. Stout, vice-president of the Society for Aircraft Activities, will preside at this evening session, which will convene as a business session of the Activity for the purpose of electing a Nominating Committee to choose the Vice-President to succeed Mr. Stout for the year 1933. The short business meeting will be followed immediately by the papers by Mr. Gatty and Mr. Upson.

### Thursday Morning's Two Papers

The Thursday morning session, convening at 10 o'clock under the chairmanship of E. E. Wilson, president of the Chance Vought Corp., is set aside for a paper on the Autogiro and another dealing with four-cylinder in-line engines.

A. E. Larsen, chief engineer of Pitcairn Aircraft, Inc., will give, for the first time, a technical analysis of the fundamental engineering features involved in Autogiro development and design in a paper on Engineering Aspects of the Modern Autogiro.

Balancing the Four-Cylinder Aircraft Engine is the title of the paper to be presented by E. S. Taylor, assistant professor of aeronautics at the Massachusetts Institute of Technology.

### Afternoon Session on Maintenance

The entire meeting, as heretofore, is being held in conjunction with the Aeronautical Chamber of Commerce of America and, with its continued recognition of the Society as its technical associate, the Chamber has cooperated through the Operations Committee of its Transport Section in arranging for the presentation at this Thursday afternoon session of a paper on Air-Transport Maintenance Problems from the Service Viewpoint, by Luther Harris, chairman of the Maintenance Subcommittee of the Chamber and maintenance engineer of the Ludington Air Lines.

The other side will be given in a paper on Maintenance as the Designer Sees It, by John G. Lee, project engineer of the American Airplane & Engine Corp.

### Medal Presentations and Speakers at Concluding Dinner

The climax of the three-day meeting will be the Aviation Dinner on Thursday night, given jointly by the Society and the Aeronautical Chamber of Commerce, with the cooperation of the Detroit Section. William B. Stout, as toastmaster, will preside over a guest table at which will be seated many of the leading figures in the industry.

The guest speaker of the evening is to be the Hon. Clarence M. Young, Assistant Secretary of Commerce for Aeronautics, whose message on this occasion will be of utmost interest and assures in advance a highly profitable and pleasant evening to those attending.

Preceding Mr. Young's address will be a short talk by **Charles L. Lawrance**, president of the Aeronautical Chamber of Commerce and Vice-President of the Society for Aircraft-Engine Engineering. This will be followed by the presentation by Vincent Bendix, Past-President of the Society, to Major James H. Doolittle, Harold S. Johnson and Beeler Blevins of the Bendix awards for winning first, second and third places, respectively, in the Bendix Trophy Race in the National Air Races in Cleveland last year. Ralph H. Upson, a member of the 1931 Wright Brothers Medal Board of Award, will then present this medal which is awarded annually by the Society.

# Comprehensive Program Planned

## *Summer Meeting at White Sulphur Springs, June 12 to 17, Will Be Interesting and Varied*

MEMBERS are beginning to ask: "By the way, what are the dates of the Summer Meeting?" Those who overlooked the announcement in the March issue of the S.A.E. JOURNAL are hereby informed that the 1932 Summer Meeting is scheduled for the middle of June, the exact dates being June 12 to 17.

White Sulphur Springs, W. Va., will be the place of the meeting, and all who have ever been there know that the location and accommodations are ideal for the Society's Summer Meeting. The surroundings are beautiful, and the physical and mechanical features, that have so much to do with the success of a meeting, are of the very best at the Greenbrier Hotel. Accommodations available for technical sessions and committee meetings are more than adequate, and facilities for recreation and relaxation are numerous, varied and attractive.

Many members who expect to attend the Summer Meeting will plan to bring their wives and daughters, as White Sulphur Springs has been very popular with the ladies at previous meetings held there, and it is anticipated that those who attend the 1932 Summer Meeting will find it even more enjoyable.

As in the past, the program will be a comprehensive one, presenting a cross-section of the Society's interests and endeavors. Sessions are being arranged by the various Professional Activities and, in addition, standards, research and general topics will receive consideration. The latest developments in automotive engineering will be outlined and discussed, and arguments for and against the various points set forth by the authors will make the sessions lively and interesting.

Chairman N. G. Shidle and other members of the Meetings Committee are making every effort to see that the different events do not conflict one with another. The Committee hopes to arrange the program in such a way that the minimum of overlapping will result.

All those concerned with the planning of the technical programs and the conduct of the sessions are determined that the full value of the sessions shall be realized, by allowing adequate time for discussion of the papers presented. As one means toward this end, sessions will start promptly at the time scheduled.

# Council Approves Diesel-Engine Research

A REGULAR meeting of the Council was held in Cleveland on Feb. 29, with President Scaife presiding. Others in attendance were Vice-Presidents Bachman, McArthur, Padgett, Poole and Roos; Councilors Duesenberg, Shidle and White; Past-President Warner and Treasurer Spicer.

A report of the Finance Committee suggesting various minor economic changes in the operation of the Society for the remainder of the present fiscal year was favorably acted upon.

Satisfactory returns were reported in connection with the Get-Your-Man membership work. Fifty-one applications for individual membership, four transfers, five reapprovals and two reinstatements were approved.

The period of June 12 to 17, inclusive, was approved as the dates for the 1932 Summer Meeting, to be held at White Sulphur Springs, W. Va. The Council also approved a proposal that the Society cooperate with the American Society for Steel Treating in the National meeting of the latter society to be held in Buffalo on Oct. 3 to 7.

An outline of the proposed joint Diesel-engine-fuel research project of the Society and the American Society of Mechanical Engineers was given and it was reported that the raising of a fund of $30,000 to $50,000 to carry out the project for a period of three years would be necessary. The program submitted was heartily approved.

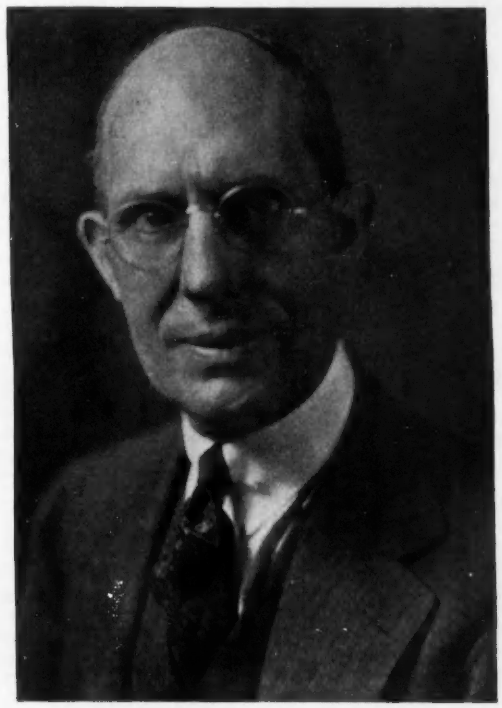
The recommendation of the Automotive Transport Code Committee that the Society accept the invitation of the Motor Vehicle Conference Committee to become a member of the latter committee was approved.

Past-President Warner was appointed as the Society's representative on the National Conference on the Relation of Law to Business with Specific Emphasis on Transportation.

Approval was granted to the Metropolitan Section to establish a local Marine Engineering Division.

# Kettering Calls on Engineers for New Ideas

## "Ket" Says



"AMERICAN Industry is at the cross-roads We've finished one job and nobody seems to know what to do next.

"Someone should think of a new plan; something new to produce or some new way to produce an old thing. It's true that our present troubles here are a part of a great world problem which mankind is facing. Post-war conditions, over - production, under-consumption; yes, they are all partly responsible, but that's not the whole story.

"We must think in fundamentals, study human needs, supply them, make new ones, supply them. New things will encourage buying, bring new production, new business. New ideas should come from engineers, from research, from minds accustomed to getting away from the conventional trends of thinking.

"To a large extent it's our job. Altogether, let's give research a chance in this country. It will start the wheels. It offers a real hope of salvation from our present difficulties."

C. F. Kettering


# They're Off! To Get Their Men

## *Membership Grades and Requirements Analyzed—Only One-Half of Annual Dues Payable until October*

As the search has just started and the horses have just left the post, we would not even hazard a guess as to who is out in front, as each mail is likely to change the picture. However, it is not too early to anticipate with considerable pleasure the finish of this race, in view of the activity and enthusiasm with which not only individual members but the Sections have proceeded with this business of educating eligible prospects in the multiple advantages of the Society.

The number of applications being received daily indicates clearly that there is no error in the belief that a large number of men in the automotive and allied industries are not only willing but anxious to take advantage of the privileges of Society membership. As has so often been repeated, either great numbers of men are waiting to be asked to join rather than appear to presume by requesting membership, or an equal or greater number, while acquainted with the work of the Society and enthusiastic about its place and progress in the automotive industry, are entirely unaware that they are eligible for inclusion in its membership. Every individual member of the Society can, if he will make an analysis of his acquaintanceship in the industry, discover several such men and with slight effort secure their applications, thus bringing to these men the many benefits of membership in the Society and to the Society the cooperation, support and the benefit of the experience of the men themselves.

### How Much Does It Cost?

This question has been asked by many prospects and undoubtedly, in many cases, the cost is a major consideration with many excellent prospects.

Your attention is called to the fact that, as the Society's fiscal year ends on Sept. 30, the present dues requirements are but one-half the annual dues. Thus, in the case of men eligible for election as Members or Associates, the cost is the initiation fee plus \$10; for Service Members, an initiation fee of \$10 plus one-half the annual dues, \$7.50; and so on for the various grades in accordance with the regular scale of dues. This fact may be of distinct advantage in many cases, as it materially reduces the initial amount required of an applicant.

By action at its meeting in January, the Council also provided that any applicant for membership in the Society will be permitted to pay his initiation fee and dues in installments. When he files his application for membership, he can pay a small amount down and the balance in regular monthly installments, provided the payment of initiation fees and dues is completed within 90 days after his election. It is understood, of course, that the prospective member does not become a fully qualified member of the Society until payment is completed.

### Don't Overlook the Juniors

In picking new member candidates, don't overlook the Junior Grade, which offers an opportunity for membership in the Society to the younger man at reduced expense. Undoubtedly many young men in your organization, and in organizations with which you come in contact, will be glad to embrace the opportunity to become Junior Members if it is presented and explained to them. The Junior Member initiation fee is only \$10, and the annual dues \$10. In the accompanying Analysis of Membership Requirements you will find an explanation of the requirements for Junior Membership.

### Associate Grade of Membership

The new membership activity since Feb. 1 has disclosed an unusual amount of misunderstanding relative to the requirements for eligibility to the Associate grade of membership. As previously stated, many men associated with the automotive industry and its allied industries have been surprised to learn that they are in any way eligible to become members. We have also found a large number of members who have been equally surprised to learn that men in various branches of the industry are qualified and for this reason have hesitated about approaching executives with a view to obtaining their applications.

To clear up this matter, not only as regards the membership requirements for the Associate grades, but for all other grades, a complete analysis of membership requirements is given herewith. This should be of much assistance to every member who is endeavoring to secure applications.

### Music Hath Charms

Congratulations are extended to the Canadian Section for one of the most novel methods of promoting interest in the Get-Your-Man campaign and at the same time providing a splendid entertainment at one of the best Section meetings held this year. On the facing page is reproduced a photograph of the Get-Your-Man quartet which was so enthusiastically received at the joint meeting of the Canadian Section of the S.A.E. and the Canadian Automobile Chamber of Commerce in the Royal York Hotel, Toronto, on March 8. Costumed as Royal Canadian Mounted Police, the quartet presented a colorful appearance and gave a decided impetus to the membership work, which, incidentally, is proceeding with great vigor in Canada.

### Intersection Contests

Apparently this contest has broken up into a series of small fights, and it appears that anybody can get in. As this is being written, word has just been received from the West Coast that Chairman Bolin, of the Northwest Section, and Chairman Drake, of the Oregon Section, have issued challenges to each other on behalf of their respective Sections to secure the greatest percentage of the quotas assigned to the Sections. Add this to the friendly rivalry that has always existed between these Sections in Seattle and Portland, and see what you get. The net result will be a great benefit to the two Sections, to which are extended best wishes for lots of recruits and a close finish.

Attention is called to the fact that the Philadelphia Section has stuck its oar into the little private contest between the Detroit and Metropolitan Sections and at the time this item is written has jumped into second place in the number of applications sent in, with Detroit leading and Metropolitan following close behind.

**Analysis of Membership Requirements**

The Constitutional requirements of the Society relative to the various grades of membership may be analyzed as follows:

Six grades of membership are provided for, as follows:

(1) Honorary Member Grade
(2) Member Grade
(3) Associate Member Grade
(4) Junior Member Grade
(5) Affiliate Member Grade
(6) Departmental Member Grade

HONORARY MEMBERS.—Acknowledged professional eminence required. Number of such members cannot exceed 1 per cent of membership at time of election.

MEMBERS.—Foreign Members and Service Members may be regarded as additional forms of Member Grade and have the same professional requirements. The only difference in the three grades is that, to become a Foreign Member, the applicant must reside in a country other than the United States, Canada, Mexico or Cuba; and, to become a Service Member, an applicant must be engaged exclusively by the United States Government.

To be eligible for Member Grade, an applicant must be not less than 26 years of age. Such membership is further limited to those who, by (*a*) technical training, (*b*) experience, and (*c*) present occupation, are qualified to

(1) Act as (*a*) designer of complete automotive apparatus or of important component part; (*b*) constructor of complete automotive apparatus or of important component parts
(2) Exercise responsible technical supervision of production of automotive parts
(3) Take responsible charge of automotive engineering work in (*a*) operation or (*b*) maintenance
(4) Impart technical instruction in (*a*) design of automotive apparatus, (*b*) construction of automotive parts or (*c*) utilization of automotive parts

Distinguished service or noteworthy accomplishment appears, in the discretion of the Council, to be desirable in addition.

ASSOCIATE MEMBERS.—There are no restrictions as to place of residence or age defining eligibility to this grade, but an applicant must be

(1) Engaged in a responsible capacity in (*a*) an automotive industry or (*b*) a related industry, in the commercial, financial or manufacturing end
(2) Connected with (*a*) an automotive industry or (*b*) a related industry and competent to cooperate with automotive engineers

JUNIOR MEMBERS.—This grade is restricted to those under 30 years of age. Junior Members may, at 26 years of age, transfer to other grades and shall so transfer when 30 years old. To qualify for this grade, an applicant must be

(1) Qualified to fill a subordinate engineering position (*a*) with an automotive industry or (*b*) in an allied industry
(2) Connected with a technical school, as (*a*) a regularly enrolled student or (*b*) a graduate

AFFILIATE MEMBERS.—Membership in this grade is limited to

(1) Firm (*a*) interested in the objects of the Society, and (*b*) shall maintain at least one personal representative designated to the Society and may designate five additional representatives
(2) Corporation; requirements (*a*) and (*b*) as above

DEPARTMENTAL MEMBERS.—This grade is limited to Government organizations interested in the objects of the Society. Membership may be granted for a period of 10 years, with the possibility of extension. A Departmental Member shall designate and maintain one personal representative.

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In brief talks on membership at the Annual Meeting in January, remarks were made by George L. McCain and B. B. Bachman as follows:

**Be Frank Regarding Eligibility**

Plenty of men are eligible for membership in the S.A.E. I have seen evidence of men who were eligible being passed up while all the effort was devoted to young men regarding whose eligibility there was perhaps some question. I should like to appeal for a little more frankness and more analysis of your man. It is perfectly possible to approach a man, discuss with him his experience and decide whether he is eligible to membership, and, if so, in what class. Failure to do this has caused some misunderstandings. Some men who thought they were eligible for full membership have been taken in as associates, and they haven't liked the idea. Those things can just as well be discussed by the man approaching the prospect.

By putting a little more thought on these applications, we can at least save the Grading Committee and the Council a great deal of work. Let's begin at the top instead of at the bottom. I feel sure that many of those men would be glad to belong to the Society.

GEORGE L. MCCAIN

**Taking Part in Activities Brings Greatest Return**

The benefits I have derived from the Society have been almost 100 per cent, because some value has to be assigned to the contacts I have made in the 22 years I have been a member.

I have met men with whom I can shake hands and call by their first names today, that I can sit down with in a corner and interchange opinions, whom I never would have come into contact with in any other way.

A few months ago a young man asked me whether I thought it was worth his while to join the Society. I gave him this answer:

> If you will participate in the activities of the Society, go into your Section and work in it—and there is room for you, because there are always more jobs than there are men—you will get more out of it than you can imagine. On the other hand, if you simply join the Society and read the S.A.E. JOURNAL, without taking an active part, I doubt whether it is worth your while.

I think that is the basis on which to talk to the men we are going to approach. If we merely sell them on the things we can point to as tangible, they probably will be disappointed in what they get.

B. B. BACHMAN

GET-YOUR-MAN QUARTET THAT PROVIDED VOCAL ENTERTAINMENT AND STIMULATED CAMPAIGN ENTHUSIASM AT THE JOINT BANQUET OF THE CANADIAN SECTION AND THE CANADIAN AUTOMOBILE CHAMBER OF COMMERCE IN TORONTO

# News of the Sections

## Notables Meet in Toronto

### *Joint Banquet Held by Canadian Section and Canadian Automobile Industry*

ON March 8 the Canadian Section joined the Canadian Automotive Chamber of Commerce in the National Motor Show Banquet at the Royal York Hotel in Toronto, which proved to be not only the largest gathering of automotive industry executives and engineers of Canada but also of those of the United States ever held outside of Uncle Sam's domain. Between 400 and 500 representatives of the industry were present and filled the great banquet hall.

The banquet was arranged to coincide with the National Motor Show held in Toronto during the week, and George W. Garner, Chairman of the Canadian Section, and D. R. Grossman, president of the Canadian Automobile Chamber of Commerce, were joint masters of ceremonies.

#### Burney and Reeves Make Addresses

The two principal speakers were Sir Dennistoun Burney, designer of the Burney rear-engined car and ex-director of design of the British airship R-100; and Alfred Reeves, vice-president and general manager of the National Automobile Chamber of Commerce of the United States. Sir Dennistoun, whose car was on exhibition at the Motor Show, made a short address along the lines of the paper he gave at the Annual Meeting of the Society in January, which was published in the S.A.E. JOURNAL for February, 1932, p. 57.

Mr. Reeves presented arguments against discrimination by governments against users of motor-vehicles in taxation and the imposition of unnecessary restrictions of the use of them. He said in part:

We have ample laws governing size, weight and speed for highway use. What we need now is law enforcement, so that the interests of all users of the road shall be properly protected.

There should also be a better understanding of what is fair taxation on the motorcar, either as merchandise or as an operated vehicle. Too many officials, at least in the United States, take the position that when money is needed the easiest place to get it is from the industry or the motorist, with no appreciation that the car is a utility vehicle, required by the poor as well as the rich, and the most heavily taxed of any nonluxury article.

We feel that if any levy is made upon industry or users of industrial products, it should be fairly distributed upon all or most products. We have cut costs and increased efficiency to give the public better cars at lower prices, and there is no reason why governments cannot effect economies too.

Mr. Reeves also urged the closest cooperation between the automobile industries of Canada and the United States, not only to speed the recovery of the industry and the consequent improvement in business conditions generally, but also for joint effort to increase the development of motor transport and highway construction on this and other continents.

Other speakers were the Hon. W. G. Martin, Minister of Public Welfare for Ontario, and Gregory Clarke, of the *Toronto Star Weekly*.

#### Novel Entertainment Feature

The entertainment was provided by a Get-Your-Man quartet—one of Canada's best male quartet, garbed in red tunics, blue riding breeches and cowboy hats of the Royal Canadian Mounted Police. The leader, Cameron Geddes, is a basso profundo of tremendous vocal volume and of international fame. This quartet feature contributed a great deal to the success of the evening.

Guest-of-honor speakers and officers and directors of the Canadian Automobile Chamber of Commerce and of the Canadian Section of the Society were seated at the speakers' table. They were:

Sir Dennistoun Burney, of London, England

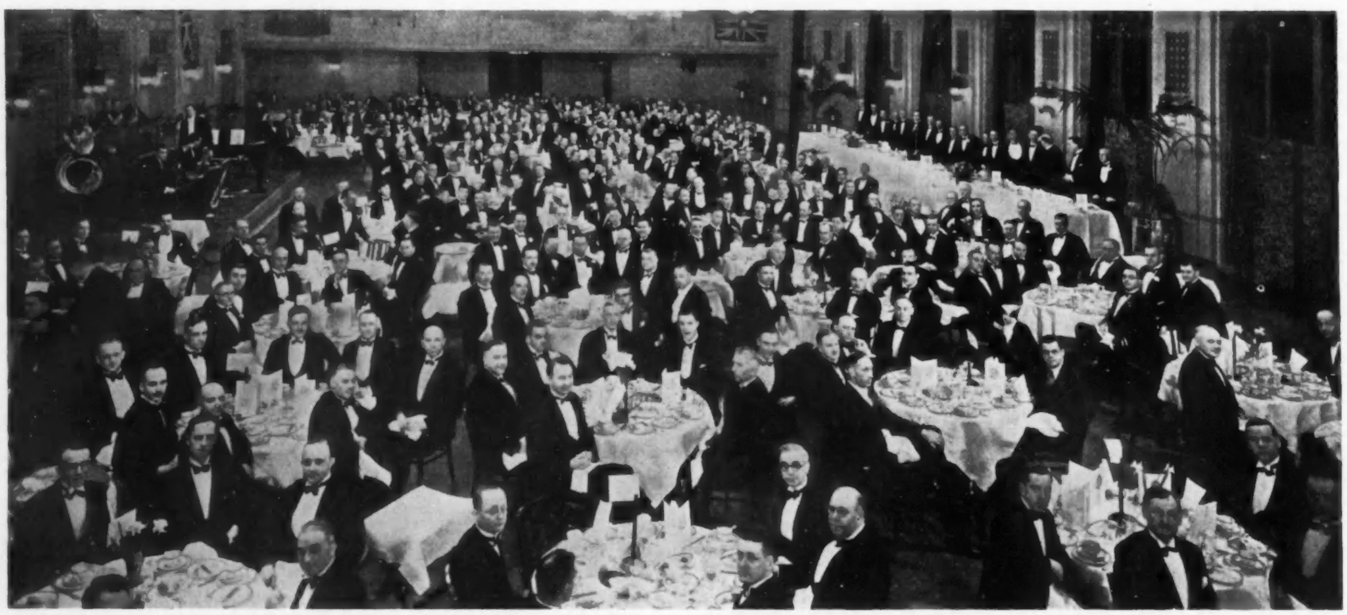
Alfred Reeves, National Automobile Chamber of Commerce

The Hon. W. G. Martin, Minister of Public Welfare for the Province of Ontario

Gregory Clarke, editor of the *Toronto Star Weekly* and author and humorist

Com. W. Briggs, British Navy ex-officer and assistant to the vice-president of General Motors of Canada

D. Ray Grossman, president of the Canadian Automobile Chamber of Commerce and



NATIONAL MOTOR SHOW BANQUET AT THE ROYAL YORK HOTEL, TORONTO, MARCH 8

Between 400 and 500 Attended This Event in Which the Canadian Section Joined with the Canadian Automotive Chamber of Commerce

vice-president of the Studebaker Corp. of Canada
T. A. Russell, vice-president of the C. A. C. C. and president of Willys-Overland of Canada and of the Massey-Harris Co.
C. E. Tilston, chief engineer of Willys-Overland, Ltd.
C. A. Brown, vice-president and general manager of General Motors of Canada
John L. Stewart, general manager of the C. A. C. C.
Wallace R. Campbell, president of the Ford Motor Co. of Canada
D. Roy Kerby, president of Dominion Motors and its subsidiary companies
A. Kreuger, general manager of the Graham Motor Car Co. of Canada
R. H. Combs, president of the Prest-O-Lite Co. of Canada
A. Barit, president of the Hudson-Essex Motor Car Co. of Canada
George W. Garner, chairman of the Canadian Section and chief engineer of General Motors of Canada
Alex Bentley, vice-chairman of the Canadian Section and vice-president and general manager of the Exide Battery Co. of Canada
Warren B. Hastings, secretary of the Canadian Section and editor of *Canadian Motorist*
W. E. Davis, treasurer of the Canadian Section and assistant general manager of General Motors of Canada

## Heavy-Haulage Units and Taxation Relief

INGENUITY that automotive engineers have exercized in taking all possible advantage of limits allowed by State laws and regulations to render heavy-haulage road vehicles most effective and economical was reviewed by R. W. Knowles, transportation engineer of The White Co., at the monthly meeting of the Cleveland Section on March 14. The other speaker was Dr. J. Gordon McKay, director of the Cleveland Regional Highway Bureau, who made an address on Taxation Relief in Cuyahoga County by Revision of Highway Financial and Administrative Policy.

The meeting was held in the Cleveland Club, where 55 members and guests enjoyed a dinner and entertainment and 30 more came later to hear the speakers.

### Can More Power Be Used?

Mr. Knowles reviewed in his paper the changes that have come in the last 12 or 15 years in heavy-haulage vehicles and their use. These were made possible by the rapid and extensive improvement of the highways and the development of motor-vehicles for hauling the largest allowable loads at relatively high speeds. Reduction of trucking costs, he pointed out, necessitated the hauling of big tonnage per transport unit and increase of vehicle speed. This, of course, required more engine power, stronger axles and driving mechanism, and the use of pneumatic tires.

By means of lantern slides of charts and photographs, Mr. Knowles illustrated how highway improvement and development of merchandise-handling vehicles have proceeded together. He showed the use of powerful trucks and tractors, semi-trailers and four-wheel trailers, both truck and trailer chassis provided with dual driving axles and wheels fitted with balloon tires, and bodies built of steel or light alloys. The best thought of truck and transportation engineers has been brought to bear on the development of means to provide load space for cargoes of the maximum legal weight on a multiplicity of axles in a transport unit or train that does not exceed the allowable length.

In view of the State limitations and the possibility of more drastic restrictions on size, weight and length, Mr. Knowles asked, "Can more horsepower be used profitably? Larger engines would reduce the time of making hauls and increase the length of haul, but higher speed calls for better braking and better, and perhaps heavier, axles, bearings and other parts. Therefore one should determine whether such a highway vehicle can make more trips or more remote deliveries and do it at a net profit.

### Highway Policies Must Change

Dr. McKay discussed the inevitable changes in the local highway policies caused by reduction in tax returns and unequal distribution of road funds caused by the Ohio Legislature, which is preponderately rural. The State and Federal highway systems are practically complete in Ohio, and for this reason the future programs will largely provide for maintenance. Funds for this cannot come from the abutting property but will come from gasoline taxes and vehicle license fees, which probably will increase greatly within a few years if our present extravagant plans for road widening are not curbed.

In commenting on Mr. Knowles's paper, Dr. McKay disagreed with Mr. Knowles regarding the size of the majority of the future trucks and their radius of operation. He predicts a 2-ton, 35-40 m.p.h. truck with a usual radius of operation of 35 to 40 miles.

A. K. Brumbaugh, of the White Co., related some early experiences in studying road impact about the time the truck industry changed from solid to pneumatic tires, and W. E. England discussed uniform traffic codes and left-hand turns.

## Die Castings and Clutch Control

TWO papers were presented and discussed at the March 9 meeting of the Syracuse Section. About two dozen members attended the meeting, which was held in the Hotel Syracuse following the usual members' dinner.

Die Castings, Their Production and Application, was the subject of the first paper, presented by J. W. During, chief engineer of the Precision Castings Co., of Syracuse.

Under the title, Starting and Automatic Clutch Control, D. L. Wertz, engineer of the Bendix Aviation Corp., of Elmira, N. Y., told of recent developments in this field of automobile engineering.

Among those who took an active part in discussion on the papers were William Metzroth and C. W. Frederick, of the Brown-Lipe-Chapin division of the General Motors Corp.; Charles P. Grimes, of the Grimes Brake Engineering Service; and Frank A. Roberts, of the Frank A. Roberts Co.

## Many Heard from in Silence Meeting at Pittsburgh

THE quest for silence in mufflers and carbureters or, in more scientific phraseology, an address on The Acoustical Treatment of Automotive Troubles, by William Jack, chief engineer of the Burgess Battery Co., resulted in a total attendance of nearly 70, of whom 40 were dinner guests, at the March 1 meeting of the Pittsburgh Section at the Fort Pitt Hotel.

Owing to illness of Arthur Tiel, Chairman of the Membership Committee of the Section, B. H. Eaton, Section Chairman, called upon emergency speakers for the Get-Your-Man campaign, and each speaker told of the benefits he had derived from membership in the Society from an entirely different angle than the others.

Keeping ahead, as the price of leadership, was emphasized by Murray Fahnestock, Section Treasurer, who told how papers presented at meetings and published in the S.A.E. JOURNAL anticipate the trend in automotive construction. The way to "get tomorrow's news today," he said, is through membership in the Society, and he also spoke of the social advantages. "Bob" Austen, sales manager of the Iron City Spring Co., spoke of the value of membership from the business angle. He told how his S.A.E. activity had brought him new friends and business contacts and said that a piston-ring had been "just a piece of iron around a hole" to him until he heard Ralph Teetor's interesting story on the personality of piston-rings.

Clyde Mathis, district service manager for The White Co., said that A. T. Colwell's paper on valves had given him entirely new ideas on the engineering aspects of valve servicing. He pointed out that automotive engineering is progressing so rapidly that only those who are willing to put in some time at such worthwhile "post-graduate courses in automotive service" as are afforded by membership in the Society are able to hold their jobs.

Charles R. Noll, automotive lubrication engineer of the Gulf Refining Co., is convinced, he said, that membership gives far greater value than it costs, and he spoke of the value of attendance at both general and Section meetings. He has found the results of S.A.E. standardization programs of everyday use and said that the exchange of ideas had been one of the basic reasons for the rapid advance of the industry.

Chairman Eaton, motor-vehicle supervisor of the Bell Telephone Co. of Pennsylvania, told how the Society had given him contacts with other fleet operators and, when some unusual problem arose, he could nearly always find some other operator who had encountered a somewhat similar problem who would help him with its solution.

Following this interchange of mem-

(*Continued on p.* 33)

# Chronicle and Comment

**The Annual April Aeronautic Meeting** THE ANNUAL Aeronautic Meeting during the National Aircraft Show will again be held at Detroit, the dates being April 5, 6 and 7. Starting with the Detroit Section Student Session on Tuesday evening and ending with the Joint Banquet of the Aeronautical Chamber of Commerce and the Society, with the cooperation of the Detroit Section, on Thursday evening, the meeting will present outstanding technical topics for discussion. A complete program and details regarding the papers are given on pp. 19 to 23 in this issue of THE JOURNAL.

**Officers Visit Western Sections** PRESIDENT A. J. SCAIFE, accompanied by Mrs. Scaife and General Manager John A. C. Warner, has just completed an extensive trip, in the course of which he visited a number of the Society's local Sections and also various groups of members in cities where no duly organized Section exists. After attending a meeting of the Chicago Section's Governing Committee and a regular meeting of the Milwaukee Section early in March, President Scaife and his party headed for the Far West. Their itinerary took them to Vancouver, Seattle, Portland, San Francisco, Los Angeles, Denver, Wichita, Kansas City and St. Louis, and in each of these places they received a warm welcome from the S.A.E. members in the vicinity.

President Scaife is enthusiastic in his expressions of appreciation regarding the flourishing condition of the Sections visited and the keen interest in S.A.E. affairs which he found to such a marked degree among Sections and informal groups alike.

**Diesel-Engine Fuel Research** YEARS ago someone made the statement that a Diesel engine would burn any kind of liquid petroleum fuel, and many persons believed this to be true even of automotive Diesel engines, until they either built or tried to run some of the latter engines. When the truth became apparent numerous explanations for the difficulties were discovered, but no one could produce conclusive evidence to prove the point. The present situation is that, on one hand, the Diesel-engine manufacturers are desirous of producing good engines if they can be assured of a satisfactory fuel and the fuel is made generally available; on the other hand, the petroleum refiners are glad to produce a satisfactory fuel if they are told what is necessary. Neither industry, however, knows the requirements of the other.

The automobile-engine industry made great progress after the automotive and petroleum industries got together and, by cooperative investigation, discovered their mutual requirements. The solution to the Diesel-engine dilemma lies along the same path; namely, cooperative investigation by the industries involved. If this is done, the future of the Diesel engine seems promising. Until this is done, there appears to be little hope for the development of this industry, which can serve a definite need in the field of automotive transportation.

A program of Diesel-fuel research aimed at a practical solution of the problem has been worked out. The investigation will be supervised and the course of the work directed by a group of representatives of the Diesel-engine and the petroleum industries, organized into a joint committee known as the Joint S.A.E.-A.S.M.E. Diesel-Fuel Research Committee. The plan involves conducting the work at a central institution, the Bureau of Standards, with the cooperation of the various technical institutions now engaged along related lines and the use of their facilities where practicable.

The acceptance of the problem by the Bureau of Standards greatly reduces the cost of such an investigation, as all of the Bureau facilities are available and some Bureau personnel can be assigned without additional cost. Furthermore, one of the great advantages of a cooperative investigation of this nature is that many companies and organizations can cooperate in financing it with only slight cost to each. Thus each organization receives in dividends from the work the benefits accruing from all that has been contributed.

Now is the time to secure this fundamental information on which to base the future development of the Diesel-engine industry and avoid the chaos that undoubtedly will result if such work is deferred until the use of the Diesel engine has become widespread.

**More About the Membership Campaign** THE S.A.E. JOURNAL has purposely omitted publishing figures on the relative standing of the Sections in the membership campaign, as it is felt that at this early date figures would be misleading. It is interesting to note, however, that, while the number of applications turned in is not the basis on which the awards will be made, the number received indicates great activity and interest in this work.

Further information on various points of interest regarding prospective members will be found on pp. 24 and 25 in this issue of THE JOURNAL.

**Mark Your Calendar Now** AN announcement of the Summer Meeting, which is to be held at White Sulphur Springs, W. Va., June 12 to 17, will be found on p. 22 of this issue of the S.A.E. JOURNAL. Additional details will be presented in the two issues next following.

**The January, 1932, S.A.E. Handbook** THE 49 NEW and revised S.A.E. Standards and Recommended Practices adopted by the Society since the Annual Meeting in January, 1931, all of which were published in the January, 1932, S.A.E. HANDBOOK, have been mailed to the members of the Society. The booklet includes suggestions as to the best way in which to use this edition in conjunction with the 1931 edition of the HANDBOOK. The form in which the January, 1932, edition has been issued is only temporary; it was adopted because of present conditions, and it is hoped that the Society will be able to return to the complete single volume when the 1933 edition is published next February. The July, 1931, Supplement sent to members last August is superseded by the January, 1932, issue and should be destroyed.

# Aerial Navigation—Methods and Equipment

Aeronautic Meeting Paper

By Harold Gatty[1]

HEREIN the author describes methods and shows instruments, tables, scales and curves used for air navigation. The ground-speed-and-drift meter devised by him and used with such remarkable success in the round-the-world flight with Wiley Post in less than nine days, on which the author was navigator, is illustrated and described.

Much has been accomplished in the last few years in providing methods and equipment for quickly and accurately determining the position and laying the correct course of aircraft, but considerable improvement remains to be made in instruments, particularly sextants.

No one method of navigation can be used under all conditions; a combination of four is necessary to achieve the best results. These four are (*a*) pilotage, or navigation by landmarks; (*b*) dead reckoning, or running a course forward from the last definitely known position by the known speed, drift and course of the plane; (*c*) celestial navigation, or ascertaining position from observations of the sun, moon and stars and correcting the course accordingly; and (*d*) radio navigation, or following a course by radio signal.

The author describes the several methods and mentions the directional gyro as the most valuable recent development both for blind flying and for maintaining an accurate and steady course under all conditions. If a course could be set and held to an error of 1 deg., and ground-speed and drift were known at all times, no other method of navigation would be needed. The author believes that eventually an automatic ground-speed-and-drift meter will be developed and navigation become more or less mechanical.

Celestial navigation has been made so simple and practical for aerial navigation by new equipment and methods that a line of position of the sun, moon or stars can be laid down in about 3½ min.; and, if precomputed curves are used, in 30 to 40 sec. An example is given of a line of position calculated from tables available for the purpose, and a method of finding the true position of the airplane is followed through. This method, which has been used only by the author and Mrs. Charles A. Lindbergh, has been highly successful.

For night navigation, the author has devised a transparent celluloid chart on which the course is laid down and which, when superimposed on a chart of star curves, enables the navigator to determine and plot a fixed position without any mathematical calculations.

A very satisfactory sextant would result, the author believes, from a combination of the best features of two sextants, one of which is compact and light and has good bubble illumination, while the other reflects the image of the sun in front of the bubble, thus eliminating the need of an astigmatizer.

AS the speed and range of aircraft are being increased, the subject of aerial navigation assumes greater importance than ever before. Much work has been accomplished in the last few years in providing suitable methods and equipment for accurate aerial navigation, but considerable room still remains for improvement in instruments, particularly sextants. While the underlying principles of marine and aerial navigation are the same their application is decidedly different.

The steamship, being comparatively slow moving in a medium that is practically fixed except for tides and currents, where velocities have a very narrow range, is seldom in danger of being carried far off course. The facilities for navigation in a surface vessel are far greater than in a plane where the navigation must be carried out in a very confined space and the vibration seriously affects the accuracy of the observation. The medium in which the plane travels is far more unstable than the sea and has a range of velocity from zero to more than 100 m.p.h. The high speed at which a plane flies and the variability in the direction and velocity of the air motion necessitate the use of quick methods of navigation that are not particularly necessary in surface navigation.

Unfortunately, no one method of navigation can be used under all conditions. A combination of four methods is necessary to achieve the best results. These four methods are pilotage, dead reckoning, celestial navigation and radio navigation.

Pilotage is the method of navigation by landmarks, beacons and the like, either previously known or picked out by reference to a map. This is the method in general use in commercial aviation. The use of pilotage is very limited, being dependent upon the pilot's abiltiy to recognize landmarks. In bad weather, over fog, water or unfamiliar territory, reliance on this method of navigation will give very uncertain results. Although pilotage is very limited in its scope, it should be used whenever possible. Distant cross bearings, ranges, two distant bearings and a run between can often be used to advantage in pilotage.

The second method of navigation, dead reckoning, should always be used in conjunction with the three other methods. The term "dead reckoning" was derived from the abbreviation "ded. reckoning," from "deduced reckoning" in the log books of the old sailing ships. So dead reckoning is the position deduced from an estimated speed and course made good. The course is always run on dead reckoning from the last definitely known position carried forward with the last known speed, drift and course made good.

An excellent plan is to mark all definite "fixes" with a small circle, with the time marked alongside, and to mark all dead reckoning positions by a cross, so that in the event of getting into thick weather, the last known position can readily be checked back to and the

[1] Chief navigation engineer, Air Corps, United States Army, Bolling Field, City of Washington.

dead reckoning or estimated course and speed worked ahead from that position.

Very accurate dead reckoning can be accomplished by the use of a good compass accurately checked for deviation and the use of an efficient ground-speed-and-drift meter. For navigational purposes, the aperiodic compass, of the type shown in Fig. 1, is far superior to all other types. It is practicable with the larger type aperiodic compass to set and steer a course to 1 deg. Owing to the absence of a card in a compass of this type, it is free from unnecessary disturbing oscillations found in card-type compasses.

The directional gyro is a most valuable recent development both for blind flying and for the maintenance of an accurate and steady course under all conditions. It is used in conjunction with a magnetic compass. The gyro will then show the course for that period without any swing whatever, and, as it shows absolute degree of turn, it takes the place of a turn indicator. The directional gyro consists of an air-spun gyroscope mounted in a case with a compass card and locking device to permit of caging the gyro so that the compass card can readily be turned to coincide with the reading of the magnetic compass. When the locking device is released, the directional gyro is in reality a non-north-seeking gyrocompass holding the set direction for about 20 min. This instrument and the gyro artificial horizon form an extremely valuable pair of instruments for blind flying and will accomplish considerable in increasing navigational efficiency and safety in flights under all weather conditions.

## The Ground-Speed-and-Drift Meter

In dead reckoning the use of an efficient ground-speed-and-drift meter is of greatest importance. Obviously, if we were able to set and hold our course to 1 deg. and to determine ground speed and drift at all times, we should need no other methods of navigation. However, this is not possible at present. I believe that eventually an automatic ground-speed-and-drift meter will be developed and navigation will become more or less mechanical. Several fixed invisible forces can be used as a basis from which ground-speed and drift can be determined. However, considerable research and experimentation will be required to develop such an instrument. When this is accomplished, it will be found equally valuable at sea and in the air.

Realizing the need for a visual ground-speed-and-drift meter, the writer has devised an instrument that will give very accurate results when the ground or water is visible. Before the development of the instrument, ground-speed was determined by timing an object along a sighting wire. This was found very inaccurate, as the object could not be seen for a long enough period to give an accurate result and also the motion of the plane seriously affected the resultant reading.


FIG. 1—APERIODIC COMPASS
Absence of a Card Renders This Type of Compass Free from Unnecessary Disturbing Oscillations, and, with the Large Type, a Course Can Be Set and Steered to an Accuracy of 1 Deg.

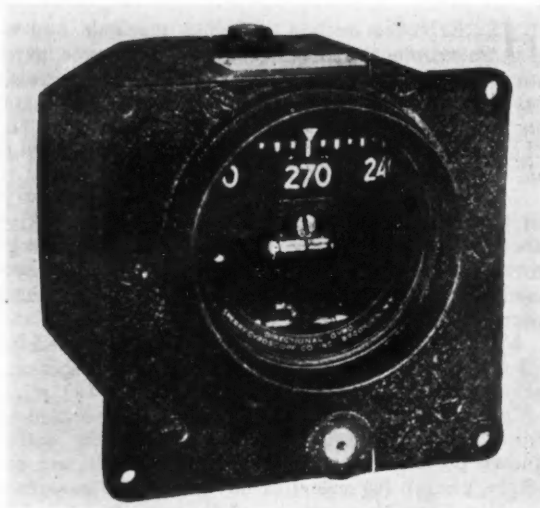



FIG. 2—THE DIRECTIONAL GYRO
Used with a Magnetic Compass, This Shows the Course without Any Swing and also the Absolute Degree of Turn. It and the Gyro Artificial Horizon Form an Extremely Valuable Pair of Instruments for Blind Flying under All Weather Conditions

This new instrument has the following features:

(1) Lightness (about 1½ lb.)
(2) Compactness
(3) Simplicity
(4) Ease of operation
(5) Observations taken from inside the plane
(6) Accuracy to 1 m.p.h.

The basic principle of the device is a constant-speed-marked film that is synchronized with the apparent motion of the ground by varying the height of the eyepiece above the film. The front section of the instrument in Fig. 3 shows how the film is carried over a prism by clockwork. The film is marked with parallel lines at right angles to the motion of the film. The side section shows how the instrument is mounted in the plane, with a periscope arrangment for viewing the ground while observing from the airplane. The diagram at the right shows the mathematical principle on which the device is constructed. Designed specially for the round-the-world flight of the Winnie Mae, 1 in. on the scale represents 1000 ft. of altitude, while a constant film speed of 0.22 in. per sec. represents a ground-speed of 150 m.p.h. The formula is by similar triangles:

$$GS : FS :: H : A,$$
$$GS = (H/A)\ FS$$
$$= 0.15\ H \text{ (in feet)}/A \text{ (in inches)}.$$

In the latest model instrument, shown in Fig. 4, the eye scale is arranged to include the constant 0.15, so that the ground-speed is determined directly by dividing

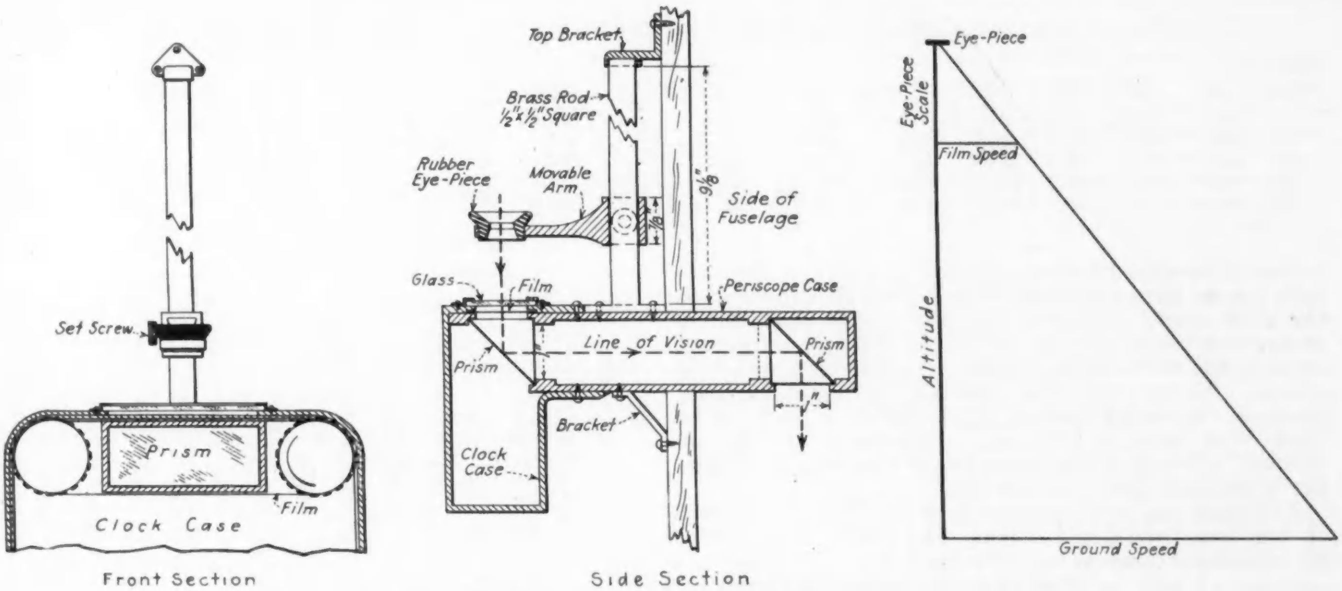



FIG. 3—VISUAL GROUND-SPEED-AND-DRIFT METER DEVISED BY THE AUTHOR

This Is Designed To Be Secured to the Side of the Fuselage with the Periscope Protruding and Has an Eyepiece Vertically Adjustable on a Scale for Making Observations from Inside the Airplane. A Constant-Speed-Marked Film Moved by Clockwork across a Prism beneath the Eyepiece Is Synchronized with the Apparent Movement of the Ground by Varying the Height of the Eyepiece. The Ground-Speed Is Ascertained by the Formu'a for Similar Triangles, as Indicated by the Diagram at the Right. The Angle of Drift Is Indicated by the Distance the Instrument Must Be Turned on a Pivot To Align Markings on the Film; Which Are at Right Angles to Its Direction of Motion, with the Apparent Ground Motion

the altitude of the plane by the scale reading. This division is accomplished by the use of a simple table. In actual operation, the altitude is read or, if flying over an unknown elevation, by flying down and measuring upward the exact altitude from the ground or water surface. The ground is observed through the eyepiece and the clockwork is started. There will be a difference between apparent speed of the film and the rate at which the ground is moving across the prism, so the eyepiece is moved until both speeds are equal, that is, until the film movement is synchronized with the apparent movement of the ground. Particularly over water, where there are no objects to time, the fact that a moving mass is used has proved of great value. This device has undergone tests by the Army Air Corps and the Navy Department and is being adopted for their use.

This ground-speed meter may be permanently mounted on the inside of the fuselage or else pivoted so that the instrument can be aligned parallel with the apparent motion of the ground below. The amount necessary to turn the instrument to accomplish this alignment is the angle of drift. Should the instrument be fixed on its mounting, the angle of drift can be determined by the use of a grid and a graduated arc. In the latter case the indicated ground-speed will be ground-speed on the heading and not the required ground-speed along the track. The actual ground-speed can be calculated by dividing the indicated ground-speed by the cosine of the angle of drift. This may be taken from Table 1.

### Deviation Card and Dead-Reckoning Tables

A card showing the deviation errors caused by the magnetism in the metal of the plane must be carried in the plane. As these errors differ on all headings, a card must be made out showing what these errors are on different headings. The true course is measured from a map, and allowance must be made for the variation due to the offset between the true-north and the magnetic poles for the locality. The deviation for that magnetic course

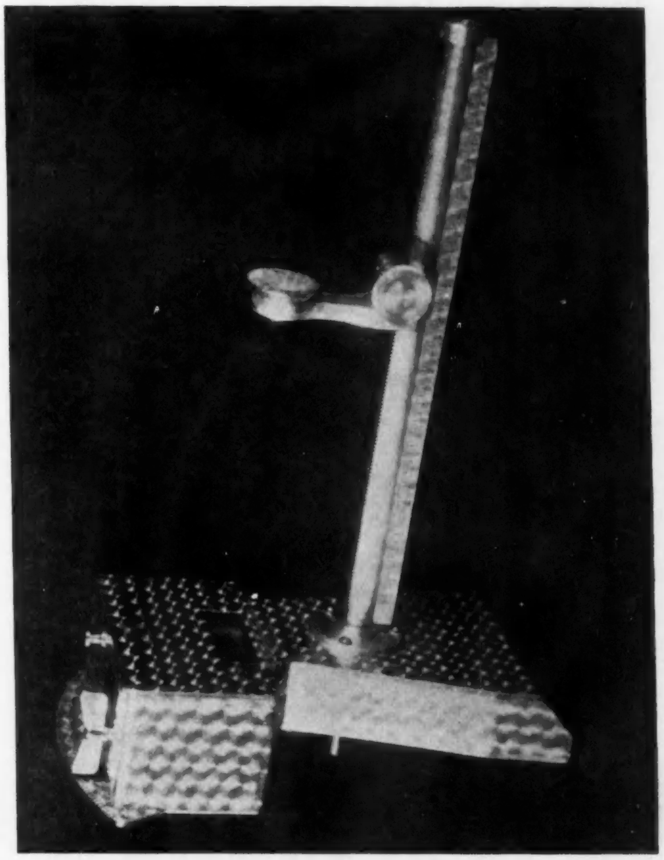


FIG. 4—LATEST MODEL OF GATTY INSTRUMENT

The Eye Scale Includes a Correction Constant, So That the Ground-Speed Is Determined Directly by Dividing the Altitude of the Plane by the Scale Reading

TABLE 1—INDICATED GROUND-SPEED TO TRUE GROUND-SPEED

| Drift, Deg. | Speed, M.P.H. 80 | 85 | 90 | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 140 | 145 | 150 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 80.3 | 85.3 | 90.4 | 95.4 | 100.4 | 105.4 | 110.4 | 115.4 | 120.5 | 125.5 | 130.5 | 135.5 | 140.5 | 145.6 | 150.6 |
| 10 | 81.2 | 86.3 | 91.4 | 96.5 | 101.5 | 106.6 | 111.7 | 116.8 | 121.9 | 126.9 | 132.0 | 137.1 | 142.2 | 147.2 | 152.3 |
| 15 | 82.8 | 88.0 | 93.2 | 98.4 | 103.5 | 108.7 | 113.9 | 119.1 | 124.2 | 129.4 | 134.6 | 139.8 | 144.9 | 150.1 | 155.3 |
| 20 | 85.1 | 90.5 | 95.8 | 101.1 | 106.4 | 111.7 | 117.1 | 122.4 | 127.7 | 133.0 | 138.3 | 143.7 | 149.0 | 154.3 | 159.6 |
| 25 | 88.3 | 93.8 | 99.3 | 104.8 | 110.3 | 115.9 | 121.4 | 126.9 | 132.4 | 137.9 | 143.4 | 149.0 | 154.5 | 160.0 | 165.5 |

is then determined from the deviation card and the compass course thus obtained. When drift is experienced, the drift angle should be applied to the true course before the variation and deviation. This is important because the drift angle results in a different magnetic course. As the deviation changes on every magnetic heading, the wrong amount of deviation is likely to be used. This point is frequently forgotten in course correction. The card recommended is the McKenzie-type deviation card illustrated in Fig. 5.

This card was the one used by Wiley Post and myself on our round-the-world flight. The heavy lines denote the standard compass and the light lines the steering compass. It will be noted that the deviations shown by the fine lines are considerably greater than the ones denoting standard-compass deviations. This is because the standard compass was installed in the cabin at a considerable distance from any magnetic metal, whereas the steering compass had to be located close to the engine. All courses were set and checked from the rear standard compass. In using the McKenzie-type card, the magnetic course is entered in the inner circle and interpolation is made by the eye to the outer circle giving the compass course to steer.

Several convenient tables are available for use in pilotage and dead reckoning. Table 2 gives the distances in miles corresponding to speeds of 70 to 200 m.p.h. for time in minutes from 1 to 60 and in hours from 2 to 9. This table may be used to find the distance covered in a given time at a given speed, to find the time required to travel a given distance at a given speed,

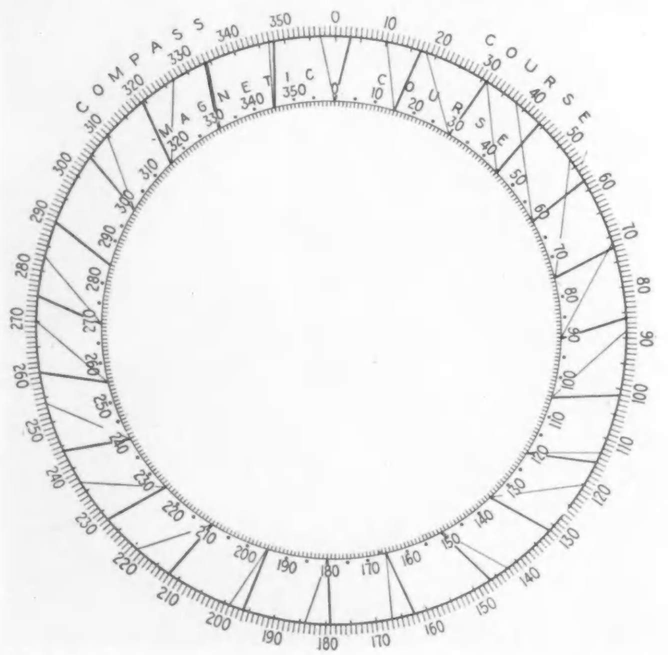



FIG. 5—MCKENZIE-TYPE CARD SHOWING DEVIATION ERRORS CAUSED BY MAGNETISM OF METAL IN THE PLANE

Heavy Lines Denote the Standard Compass, and Light Lines the Steering Compass

TABLE 2—SPEED-TIME-DISTANCE TABLE

| TIME IN MINUTES | 70 | 80 | 90 | 100 | 110 | 120 DISTANCE | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.2 | 1.3 | 1.5 | 1.7 | 1.8 | 2 | 2.2 | 2.3 | 2.5 | 2.7 | 2.8 | 3 | 3.2 | 3.3 |
| 2 | 2.3 | 2.7 | 3 | 3.3 | 3.7 | 4 | 4.3 | 4.7 | 5 | 5.3 | 5.7 | 6 | 6.3 | 6.7 |
| 3 | 3.5 | 4 | 4.5 | 5 | 5.5 | 6 | 6.5 | 7 | 7.5 | 8 | 8.5 | 9 | 9.5 | 10 |
| 4 | 4.7 | 5.3 | 6 | 6.7 | 7.3 | 8 | 8.7 | 9.3 | 10 | 10.7 | 11.3 | 12 | 12.7 | 13.3 |
| 5 | 5.8 | 6.7 | 7.5 | 8.3 | 9.2 | 10 | 10.8 | 11.7 | 12.5 | 13.3 | 14.2 | 15 | 15.8 | 16.7 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 7 | 8.2 | 9.3 | 10.5 | 11.7 | 12.8 | 14 | 15.2 | 16.3 | 17.5 | 18.7 | 19.8 | 21 | 22.2 | 23.3 |
| 8 | 9.3 | 10.7 | 12 | 13.3 | 14.6 | 16 | 17.3 | 18.7 | 20 | 21.3 | 22.7 | 24 | 25.3 | 26.7 |
| 9 | 10.5 | 12 | 13.5 | 15 | 16.4 | 18 | 19.5 | 21 | 22.5 | 24 | 25.5 | 27 | 28.5 | 30 |
| 10 | 11.7 | 13.3 | 15 | 16.3 | 18.3 | 20 | 21.7 | 23.3 | 25 | 26.7 | 28.3 | 30 | 31.7 | 33.3 |
| 11 | 13 | 15 | 17 | 18 | 20 | 22 | 24 | 26 | 28 | 29 | 31 | 33 | 35 | 37 |
| 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| 13 | 15 | 17 | 20 | 22 | 24 | 26 | 28 | 30 | 33 | 35 | 37 | 39 | 41 | 43 |
| 14 | 16 | 19 | 21 | 23 | 26 | 28 | 30 | 33 | 35 | 37 | 40 | 42 | 44 | 47 |
| 15 | 18 | 20 | 23 | 25 | 27 | 30 | 33 | 35 | 38 | 40 | 43 | 45 | 48 | 50 |
| 16 | 19 | 21 | 24 | 27 | 29 | 32 | 35 | 37 | 40 | 43 | 45 | 48 | 51 | 53 |
| 17 | 20 | 23 | 26 | 28 | 31 | 34 | 37 | 40 | 43 | 45 | 48 | 51 | 54 | 57 |
| 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 | 51 | 54 | 57 | 60 |
| 19 | 22 | 25 | 29 | 32 | 35 | 38 | 41 | 44 | 48 | 51 | 54 | 57 | 60 | 63 |
| 20 | 23 | 27 | 30 | 33 | 37 | 40 | 43 | 47 | 50 | 53 | 57 | 60 | 63 | 67 |
| 21 | 24 | 28 | 32 | 35 | 38 | 42 | 46 | 49 | 53 | 56 | 60 | 63 | 66 | 70 |
| 22 | 26 | 29 | 33 | 37 | 40 | 44 | 48 | 51 | 55 | 59 | 62 | 66 | 70 | 73 |
| 23 | 27 | 31 | 35 | 38 | 42 | 46 | 50 | 54 | 58 | 61 | 65 | 69 | 73 | 77 |
| 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 |
| 25 | 29 | 33 | 38 | 42 | 46 | 50 | 54 | 58 | 63 | 67 | 71 | 75 | 79 | 83 |
| 26 | 30 | 35 | 39 | 43 | 48 | 52 | 56 | 61 | 65 | 69 | 74 | 78 | 82 | 87 |
| 27 | 31 | 36 | 41 | 45 | 49 | 54 | 59 | 63 | 68 | 72 | 77 | 81 | 85 | 90 |
| 28 | 33 | 37 | 42 | 47 | 51 | 56 | 61 | 65 | 70 | 75 | 80 | 84 | 89 | 93 |
| 29 | 34 | 39 | 44 | 48 | 53 | 58 | 63 | 68 | 73 | 77 | 82 | 87 | 92 | 97 |
| 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
| 31 | 36 | 41 | 47 | 52 | 57 | 62 | 67 | 72 | 78 | 83 | 88 | 93 | 98 | 103 |
| 32 | 37 | 43 | 48 | 53 | 59 | 64 | 69 | 75 | 80 | 85 | 91 | 96 | 101 | 107 |
| 33 | 38 | 44 | 50 | 55 | 60 | 66 | 72 | 77 | 83 | 88 | 94 | 99 | 105 | 110 |
| 34 | 40 | 45 | 51 | 57 | 62 | 68 | 74 | 79 | 85 | 91 | 96 | 102 | 108 | 113 |
| 35 | 41 | 47 | 53 | 58 | 64 | 70 | 76 | 82 | 88 | 93 | 99 | 105 | 111 | 117 |
| 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 | 102 | 108 | 114 | 120 |
| 37 | 43 | 49 | 56 | 62 | 68 | 74 | 80 | 86 | 93 | 99 | 105 | 111 | 117 | 123 |
| 38 | 44 | 51 | 57 | 63 | 70 | 76 | 82 | 89 | 95 | 101 | 108 | 114 | 120 | 127 |
| 39 | 45 | 52 | 59 | 65 | 71 | 78 | 85 | 91 | 98 | 104 | 110 | 117 | 123 | 130 |
| 40 | 47 | 53 | 60 | 67 | 73 | 80 | 87 | 93 | 100 | 107 | 113 | 120 | 127 | 133 |
| 41 | 48 | 55 | 62 | 68 | 75 | 82 | 89 | 96 | 103 | 109 | 116 | 123 | 130 | 137 |
| 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 98 | 105 | 112 | 119 | 126 | 133 | 140 |
| 43 | 50 | 57 | 65 | 72 | 79 | 86 | 93 | 100 | 108 | 115 | 122 | 129 | 136 | 143 |
| 44 | 51 | 59 | 66 | 73 | 81 | 88 | 95 | 103 | 110 | 117 | 125 | 132 | 139 | 147 |
| 45 | 52 | 60 | 68 | 75 | 82 | 90 | 98 | 105 | 113 | 120 | 128 | 135 | 143 | 150 |
| 46 | 54 | 61 | 69 | 77 | 84 | 92 | 100 | 107 | 115 | 123 | 130 | 138 | 146 | 153 |
| 47 | 55 | 63 | 71 | 78 | 86 | 94 | 102 | 110 | 118 | 125 | 133 | 141 | 149 | 157 |
| 48 | 56 | 64 | 72 | 80 | 88 | 96 | 104 | 112 | 120 | 128 | 136 | 144 | 152 | 160 |
| 49 | 57 | 65 | 74 | 82 | 90 | 98 | 106 | 114 | 123 | 131 | 139 | 147 | 155 | 163 |
| 50 | 58 | 67 | 75 | 83 | 92 | 100 | 108 | 117 | 125 | 133 | 142 | 150 | 158 | 167 |
| 51 | 59 | 68 | 77 | 85 | 93 | 102 | 111 | 119 | 128 | 136 | 145 | 153 | 162 | 170 |
| 52 | 61 | 69 | 78 | 87 | 95 | 104 | 113 | 121 | 130 | 139 | 147 | 156 | 165 | 173 |
| 53 | 62 | 71 | 80 | 88 | 97 | 106 | 115 | 124 | 133 | 141 | 150 | 159 | 168 | 177 |
| 54 | 63 | 72 | 81 | 90 | 99 | 108 | 117 | 126 | 135 | 144 | 153 | 162 | 171 | 180 |
| 55 | 64 | 73 | 83 | 92 | 101 | 110 | 119 | 128 | 138 | 147 | 156 | 165 | 174 | 183 |
| 56 | 65 | 75 | 84 | 93 | 103 | 112 | 121 | 131 | 140 | 149 | 159 | 168 | 177 | 187 |
| 57 | 66 | 76 | 86 | 95 | 104 | 114 | 123 | 133 | 143 | 152 | 162 | 171 | 181 | 190 |
| 58 | 68 | 77 | 87 | 97 | 106 | 116 | 126 | 135 | 145 | 155 | 164 | 174 | 184 | 193 |
| 59 | 69 | 79 | 89 | 98 | 108 | 118 | 128 | 138 | 148 | 157 | 167 | 177 | 187 | 197 |
| 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 |
| HOURS | | | | | | | | | | | | | | |
| 2 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 320 | 340 | 360 | 380 | 400 |
| 3 | 210 | 240 | 270 | 300 | 330 | 360 | 390 | 420 | 450 | 480 | 510 | 540 | 570 | 600 |
| 4 | 280 | 320 | 360 | 400 | 440 | 480 | 520 | 560 | 600 | 640 | 680 | 720 | 760 | 800 |
| 5 | 350 | 400 | 450 | 500 | 550 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 |
| 6 | 420 | 480 | 540 | 600 | 660 | 720 | 780 | 840 | 900 | 960 | 1020 | 1080 | 1140 | 1200 |
| 7 | 490 | 560 | 630 | 700 | 770 | 840 | 910 | 980 | 1120 | 1120 | 1190 | 1260 | 1330 | 1400 |
| 8 | 560 | 640 | 720 | 800 | 880 | 960 | 1040 | 1120 | 1200 | 1280 | 1360 | 1440 | 1520 | 1600 |
| 9 | 630 | 720 | 810 | 900 | 990 | 1080 | 1170 | 1260 | 1350 | 1440 | 1530 | 1620 | 1710 | 1800 |

or to find the speed necessary to cover a given distance in a given time.

Using Table 3, and knowing the distance flown and the distance off the original track course, we can find the course correction, the correction to parallel a course, or the correction to allow for the distance off course, and also the course correction to steer a certain distance to the right or left of a course in a given distance.

### Aids to Celestial Navigation

Considerable valuable work has been done recently in making celestial navigation practical for aerial navigation. The slow and tedious methods used in marine navigation were found impractical for air use. With the present equipment and methods, it is now possible to lay down a line of position of the sun, moon or stars in about 3½ min. When precomputed curves are used

for the sun or moon, the actual time necessary for laying down a line of position is about 30 or 40 sec. A line of position is a line on which the observer is known to be. The intersection of two lines of position determines what is known as a "fix," or a fixed position.

In the daytime, when the sun is the only visible celestial body, only one line of position can be determined from it at one time, although observations taken about 2 hr. apart will give a fix by using the dead-reckoning run between and running the first position line up to the second. The accuracy of a fix obtained in this manner depends upon the accuracy of the dead reckoning line between observations. Use of the moon in the daytime is very valuable, as a line of position obtained from the moon can be instantly crossed with a line from the sun and a fix thus determined.

We are particularly indebted to Lieut.-Com. P. V. H. Weems, of the Hydrographic Office of the United States Navy, for his foresight and tireless efforts in the cause of aerial navigation. His line-of-position tables have paved the way for rapid solution of the line of position. It is believed that the recent publication, Aerial and Marine Navigation Tables, by Lieut. John E. Ginrich, provides the simplest solution for the calculation of a line of position. These are practically the same as Weem's tables, with the exception that the azimuth is taken from the tables instead of from a diagram. My opinion is that a table is superior to a diagram for use in the air. An example of a line of position calculated from the Ginrich tables follows:

**On April 6, 1932, a plane flying from the City of Washington to Detroit observes the sun for a line of position *GCT* 16 hr. 20 min. 30 sec; sextant altitude, 52 deg. 10 min.; *DR* position, 41 deg. 20 min. N, 80 deg. 15 min. W.**

| | | | | | |
|---|---|---|---|---|---|
| | *Hs* 52 deg. 10 min. | | | | Sextant altitude |
| | Corr. — 1 min. | | | | Refraction |
| | *Ho* 52 deg. 09 min. | | | | Corrected sextant altitude |
| | Hr. | Min. | Sec. | | |
| *GCT* | 16 | 20 | 30 | | Greenwich Civil Time, carried on watch |
| *Eq* of *T* | | −2 | 25 | | Equation of time, from Nautical Almanac |
| *GAT* | 16 | 18 | 05 | | Greenwich Apparent Time |
| *GHA* | 4 | 18 | 05 | | Greenwich hour angle, in time |
| | Deg. | Min. | | | |
| *GHA* (arc) | 64 | 31 | | W | Greenwich hour angle, in arc |
| Long (ass) | 80 | 31 | | W | Assumed longitude, same minutes as *GHA* |
| *LHA* | 16 | | | E | Local hour angle |
| Lat (ass) | 41 | | | N | Assumed latitude, nearest whole degree |
| Dec | 6 | 33 | | N | Declination of the sun, from Nautical Almanac |
| *K* | 42 | 07.4 | | N | Element from line-of-position tables, named same as latitude |
| *K*∼*D* | 35 | 34.4 | | | Algebraic sum of *K* and Dec. Same names subtract |
| *A* | 960.7 | | | | Element from tables |
| *B* | 8971 | | | | Element from tables |
| *A* + *B* | 9931.7 | | | | Sum of *A* and *B* |
| | Deg. | Min. | | | |
| *Hc* | 52 | 43 | | | Calculated altitude for assumed position |
| *Ho* | 52 | 09 | | | Corrected sextant altitude at actual position |
| *A* | | 34 | Away | | Actual line of position 34 miles away from the sun from assumed position |
| *X* | 3.032 | | | S | Element from table |
| *Y* | 0.413 | | | N | Element from table |
| *X*∼*Y* | 2.619 | | | S | Algebraic sum of *X* and *Y* |
| | Deg. | | | | |
| *Z* | S 27 E | | | | Azimuth, or bearing of sun from assumed position |

TABLE 3—COURSE ERRORS FOR DISTANCES OFF COURSE

| Miles flown | Miles off course | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 | 25 | 30 | 40 | 50 |
| | Compass correction to parallel track course | | | | | | | | | | | | | | | |
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 10 | 6 | 12 | 17 | 24 | 30 | 37 | 44 | 53 | 64 | 90 | | | | | | |
| 20 | 3 | 6 | 9 | 12 | 14 | 17 | 20 | 24 | 27 | 30 | 49 | 90 | | | | |
| 30 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 15 | 17 | 19 | 30 | 42 | 56 | 90 | | |
| 40 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 14 | 22 | 30 | 39 | 49 | 90 | |
| 50 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 17 | 24 | 30 | 37 | 53 | 90 |
| 60 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 14 | 19 | 25 | 30 | 42 | 56 |
| 70 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 12 | 17 | 21 | 25 | 35 | 46 |
| 80 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 11 | 14 | 18 | 22 | 30 | 39 |
| 90 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 6 | 10 | 13 | 16 | 19 | 26 | 34 |
| 100 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 9 | 12 | 14 | 17 | 24 | 30 |
| 110 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 8 | 10 | 13 | 16 | 21 | 27 |
| 120 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 7 | 10 | 12 | 14 | 19 | 25 |
| 130 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4 | 7 | 9 | 11 | 13 | 18 | 23 |
| 140 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 6 | 8 | 10 | 12 | 17 | 21 |
| 150 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 6 | 8 | 10 | 12 | 15 | 19 |
| 160 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 | 5 | 7 | 9 | 11 | 14 | 18 |
| 170 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 5 | 7 | 8 | 10 | 14 | 17 |
| 180 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 5 | 6 | 8 | 10 | 13 | 16 |
| 190 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 5 | 6 | 8 | 9 | 12 | 15 |
| 200 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 6 | 7 | 9 | 12 | 14 |

### Quick Method of Plotting Lines of Position

The result of this calculation gives us the calculated altitude for the assumed position, the true bearing of the sun from the assumed position and the difference between the sextant altitude at our actual position and the calculated altitude at our assumed position. We next plot our assumed position on our map and the true bearing of the sun at that position, and then plot along that bearing the number of minutes of our difference in altitude, toward the sun if the observed altitude is greater than the calculated and away from the sun if it is less. Each minute of altitude corresponds to a nautical mile on the ground.

From this point on our azimuth line we drop a perpendicular, and this is our line of position. The operation of calculating and plotting a line of position should take about 4 min.

In order that lines of position may be determined more rapidly in the air on extended flights, we may previously compute our altitudes for every 20 min. for our course and construct a curve of altitude against Greenwich Civil Time. Having this curve, all that needs to be done in the air is to take our sextant altitude and *GCT* and plot it on our curve sheet, and we see immediately the altitude difference to be plotted along the azimuth line. In this way a line of position may be obtained in 30 or 40 sec.

To obtain a satisfactory curve, the sextant altitudes are computed for every 20 min. of *GCT*. We choose, near our intended time of departure, a *GAT* (Greenwich Apparent Time) evenly divisible by 4 min., giving us an even degree of Greenwich hour angle and making the calculations much easier. The *GCT* needed for plotting is obtained by applying the equation of time to the *GAT* chosen.

Working down to our *Hc*, or calculated altitude, and azimuth, the assumed position and the *DR* position are plotted. The azimuth is then drawn from the assumed position. The correct altitude for our *DR* position is found by plotting along the azimuth line. By applying the bubble-sextant correction (refraction), using the reverse sign, we obtain the sextant altitude for the *GCT* at our *DR* position. This is worked at even 20-min.

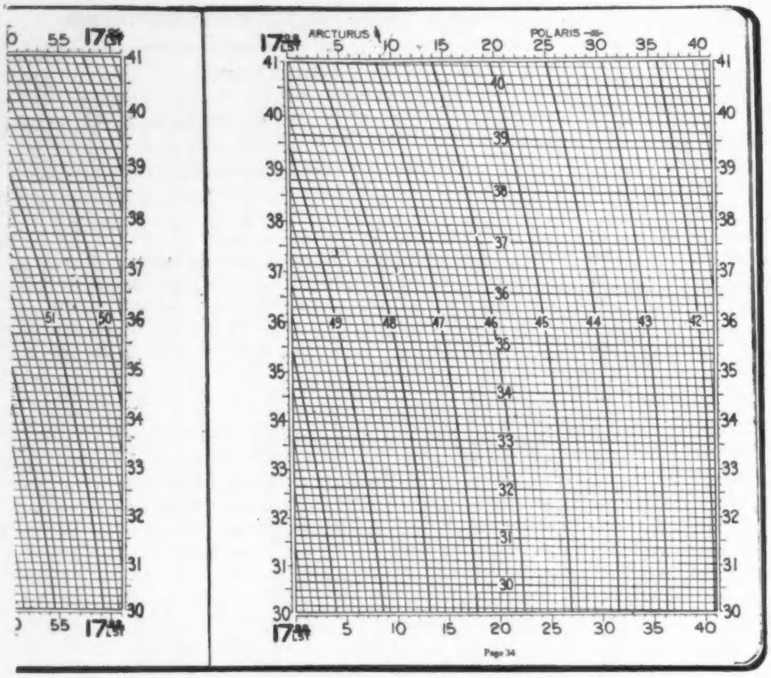



FIG. 6—WEEMS STAR CURVES

Use of These Curves Makes Possible the Solution of a "Fix" from Two Stars in Less than 1 Min.

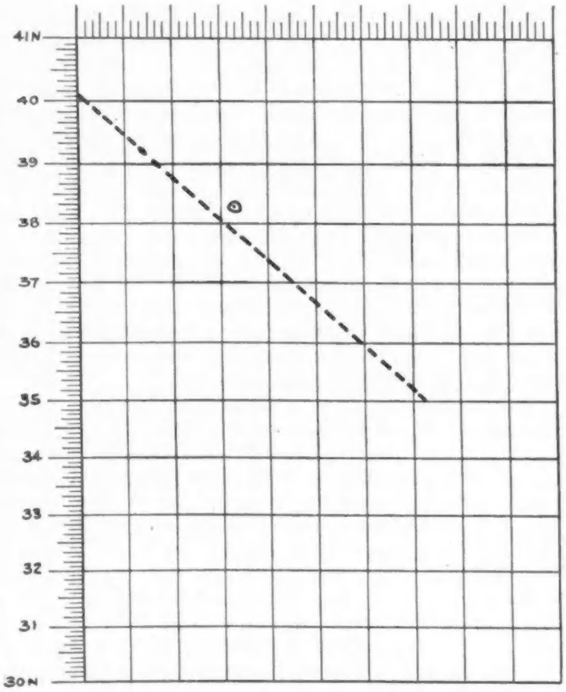



FIG. 7—GATTY TRANSPARENT CHART FOR USE WITH STAR CURVES

With the Course Laid Down on This Chart, Superimposing the Chart on the Star Curves Enables the Navigator To Determine and Plot a "Fix" without any Mathematical Calculations

intervals for our intended track and the curve constructed.

This method has been used very successfully by the writer on cross-country flights and also on the round-the-world flight. Up to the present the only other person to use this method is Mrs. Charles A. Lindbergh, who navigated for her husband on their record flight from Los Angeles to New York City. Mrs. Lindbergh navigated entirely by celestial navigation and dead reckoning and obtained excellent results with the precomputed curves. Few persons realize that she is an expert navigator and would put any transport pilot to shame with her all-round knowledge of navigation.

When the precomputed curve is constructed, observations can be made at any time during the flight and do not have to be taken at the 20 min. intervals.

When, on any course, the sun is abeam, the result of the observation will show the observer whether he is to the right or left of his course. If the sun be ahead or astern, an observation will indicate the actual groundspeed of the plane. Even if the curve is not constructed prior to taking off it will be found advisable to construct it after the plane is on the air, thereby reducing the number of calculations, and observations may be made as frequently as desired.

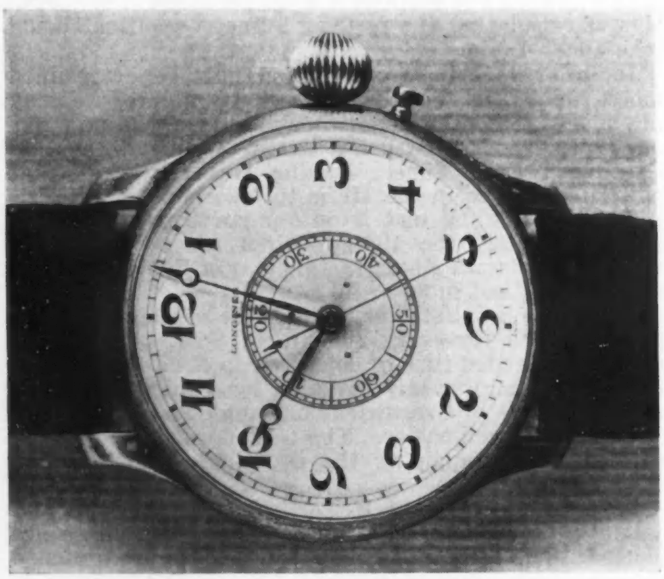


FIG. 8—WEEMS SECOND-SETTING WATCH

The Second Dial Can Be Rotated To Eliminate the Error of the Second Hand

### Star Curves and Chart for Night Navigation

Navigation at night is much more accurate than during the day. In the daytime we have only one celestial body to observe, from which we can obtain only one line of position, except when the moon is visible; whereas at night we have all the stars from which to work any number of lines of position. The use of the Weems Star Curves shown in Fig. 6 makes possible the solution of a fix from two stars in less than 1 min.

The writer has devised a transparent celluloid chart, graduated in latitude and longitude, on which the course is laid down and which, when superimposed on the star curves, enables the navigator to determine and plot a fix without any mathematical calculations. The transparent chart is placed over the curve sheet and aligned horizontally until a zero point on the chart coincides with the minutes of Greenwich Sidereal Time (read from *GST* watch). The intersection of the sextant altitudes of the two stars is marked on the chart. This shows the actual position of the plane with reference to the plotted course, or in terms of latitude and longitude.

(*Concluded on p. 170*)

# Flight Control by Air Visualization

**Aeronautic Meeting Paper**

**By Ralph H. Upson**[1]

BLIND flying without special training, together with general improvement in flight control, is possible with a new simplified type of artificial horizon. The instrument in most respects provides a safer reference for control than does the natural horizon, because it deals directly with the real source of control, which is the air.

Air is to the airplane as the road to an automobile; the different movements of the airplane relative to its own road of air primarily determine its control. To make such movements visible is a function of instruments, but a set of several different instruments to show separate movements of the airplane is unnecessarily complicated and expensive. A single instrument giving the unity and simplicity of the natural horizon but having a directness of reading that can be obtained only from the directly adjacent air is the remedy.

The new instrument, called the Air-I-Zon, serves as an aerodynamic horizon by presenting a visualization of the air through which the plane is flying. This provides a simple reference relative to which all essential changes in the lateral and longitudinal attitude of the airplane are immediately apparent. The principles involved and the practical development of the instrument are described in the paper.

CONCEIVED originally as something simple, the airplane has since grown mainly by an accretion of afterthoughts. As a result, the completely equipped plane of today is a complicated assembly of individually well-studied but more or less unrelated parts. While recognizing the value of each individual addition, it seems to be time now to study the total result for the purpose of combining various functions, subordinating the parts to the whole, and re-creating a coordinated unit in which simplicity is once more the outstanding characteristic. Nowhere is the need for this more evident than on the instrument board.

The present complications are found not so much in the navigation instruments themselves as in the flight-control instruments; that is, those which minister to reasonably straight, level flight within a safe range of attitude. Problems connected with the use of such instruments have been treated by F. W. Meredith[2], William G. Brown[3], and W. C. Ocker and Carl J. Crane[4]. The early instruments, such as lateral and longitudinal inclinometers, were simple enough but ineffective by themselves. Hence they had to be supplemented by others, and these in turn by still others, like the fleas on Mark Twain's dog.

Thus we have today the following flight-control in-

[1] M.S.A.E.—University of Michigan, Ann Arbor, Mich.

[2] For dangers of following the bank indicator, see *Journal of the Royal Aeronautical Society*, February, 1931, p. 75.

[3] For dangers due to the necessity of following many instruments, see *Aviation Engineering*, January, 1930, p. 21.

[4] For the importance of simplifying the flier's job, with a proposed mechanical solution, see Blind Flying and Its Teaching, paper presented at a meeting of the American Society of Mechanical Engineers held in Baltimore, May 12 to 14, 1931.

## List of Symbols Used in the Paper

$a$ = distance between legs of U-tube, inches
$B$ = distance between wing-tip orifices, feet
$C_L$ = coefficient of lift
$F$ = centrifugal force acting on airplane during a turn, pounds
$f$ = function
$g$ = acceleration due to gravity
$h$ = difference in height of liquid between reservoir tube and tube indicating longitudinal attitude, inches
$\triangle h$ = difference in height of liquid in the two legs of transverse U-tube, measured parallel to the legs, inches
$K$ = suction coefficient, values given in Table 1.
$L$ = gross lift, normal to air path and span, including inertia force, pounds
$N$ = load factor $= L/W = C_L q/(W/S)$
$P$ = net pressure difference on liquid, pounds per square foot
$P_a$ = aerodynamic suction difference, pounds per square foot
$P_g$ = gravity pressure of liquid, pounds per square foot
$P_{ia}$ = inertia pressure of air, pounds per square foot
$P_{il}$ = inertia pressure of liquid, pounds per square foot
$p$ = undisturbed airfoil pressure at orifice position in straight flight, pounds per square foot
$p'$ = local pressure of air in an orifice, pounds per square foot
$q$ = impact pressure $= \frac{1}{2}\rho V^2$
$R$ = radius of turning circle, assumed to be horizontal, at center of gravity, feet
$R_z$ = vertical radius of turn, feet
$S$ = total supporting area, square feet
$t$ = elapsed time from application of maneuver or gust, seconds
$V$ = air-speed of airplane, feet per second
$v$ = local velocity of air relative to an orifice, feet per second
$v_1$ = velocity of inner orifice during a turn, feet per second
$v_2$ = velocity of outer orifice during a turn, feet per second
$u$ = upward velocity of gust, feet per second
$w$ = upward velocity of center of gravity of airplane, feet per second
$W$ = total weight of the airplane, pounds
$\alpha$ = angle of attack relative to conventional chord line
$\alpha_0$ = angle of attack relative to zero lift line
$\beta$ = angle of bank or slip, relative to horizontal
$\gamma$ = angle of bank or slip relative to liquid level in U-tube
$\rho$ = mass density of air, slugs per cubic foot

struments, serving, with varying degrees of success, the functions indicated by their names:

(1) Bank indicator, to show the lateral angle relative to the gravity-inertia vector
(2) Pitch indicator, less common, to show longitudinal angle relative to the same; or rate of pitching, if gyroscopic
(3) Gyroscopic horizon, to show combined lateral and longitudinal change of angle relative to the previously established flight attitude
(4) Climb indicator, to show rate of change in altitude
(5) Air-speed meter, to show rate of progress along the flight path
(6) Directional gyro, or turn indicator, to show change, or rate of change, in directional angle

Not all of these instruments are strictly necessary; but to achieve blind flight satisfactorily is hardly possible with less than four of them, and then only after thorough training. It seems to be a case of tripping over the very multiplicity of our ingenious mechanical devices.

### The Choice of a Reference

In hunting a solution, it is instructive to consider first the only single reference which has hitherto served as a guide to flight control, the natural or geographic horizon. However, to suppose that, because it is natural, it is necessarily ideal is certainly jumping at a conclusion, because

(1) It has no quantitative significance.
(2) Its position for one throttle setting is no criterion for another.
(3) It makes no allowance for the air conditions immediately surrounding the airplane.
(4) There is no guarantee that the visible horizon is even level.
(5) For a variety of conditions, it may not be visible at all.

The natural horizon still has one big advantage, that it costs nothing; yet, everything considered, it would seem strange if we could not devise a horizon substitute that would be far better than the original.

Unfortunately, a gyroscopic reference suffers inherently from most of the disadvantages of the natural horizon. The underlying reason is the same; it is a reference that, by its very nature, is wholly foreign to the immediate problem of airplane control. Although analogies are always dangerous, I hazard the comparison with an automobile. Do we hear any suggestions that a motor-car should be controlled, in the direct and immediate sense, by reference to a distant cloud or to a gyroscope? How else could it be satisfactorily controlled but by direct reference to the road over which it is traveling?

As the air stands in similar relation to the airplane, it is indeed surprising that indirect control references work at all. That they do is because the average air is much smoother and more consistent than the average road, and the power requirements in aircraft are more constant. Still the number of accidents from stalls, spins, dives, over-control and under-control, even with the horizon clearly visible, seems sufficient justification for assuming that *all flying is blind flying* unless the pilot has some means of seeing the air through which he flies.

The foregoing generalization is as far as the analogy with the automobile can be carried, for we can choose to "see" the air in any one or more of its several aspects. First, as an example of how not to do it, let us consider one of the conventional instruments that is clearly based on air reference, the much used and abused air-speed meter.

Although it is a good instrument for special flight tests, simple and direct as far as it goes, the air-speed meter, more properly a dynamic pressure meter, is sadly deficient as a practical instrument for flight control.

In the first place, although the pilot may think and talk in terms of speed, what he is really most interested in is the angle of attack relative to the air path on which he is flying, which almost alone determines the facility and safety of control. For normal conditions, this angle of attack is a direct function of the dynamic pressure, and therefore of the speed, but unfortunately there are several important exceptions:

(1) The relation fails to hold for varying load.
(2) On a sudden change of angle, it takes time for the change in speed and dynamic pressure to materialize.
(3) On approaching a stall, the speed and dynamic pressure become virtually constant, although the angle may be rapidly increasing.

Accordingly, the air-speed meter, by the very principle of its operation, cannot distinguish between widely different angles or conditions of control at the time when the pilot most needs the information.

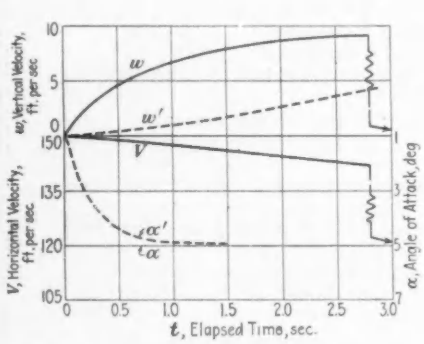



Fig. 1—Effect of Pulling Back To Increase Angle of Attack from 1 to 5 Deg. Initial Velocity Is 150 Ft. per Sec. (102 M.P.H.)

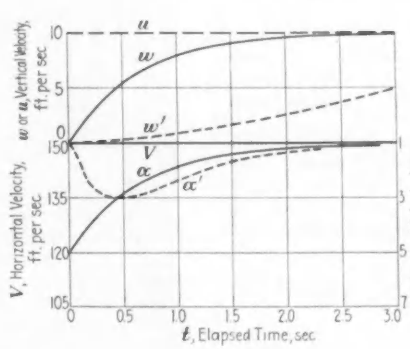



Fig. 2—Effect of Striking an Upward Gust of 10 Ft. per Sec., Increasing Angle from 1 to 5 Deg. Initial Velocity Is 150 Ft. per Sec. (102 M.P.H.)

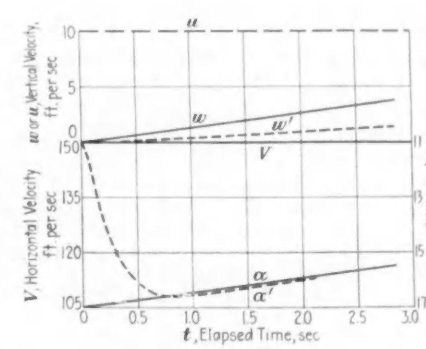



Fig. 3—Effect of Striking an Upward Gust of 10 Ft. per Sec., Increasing Angle from 11 to 17 Deg Initial Velocity Is 100 Ft. per Sec. (68 M.P.H.)

EFFECT ON SPEED, CLIMB AND ANGLE OF AN AIRPLANE FROM A SUDDEN INCREASE IN ITS ANGLE OF ATTACK

The Machine Considered Is a Monoplane Having a Span of 40 Ft., an Aspect Ratio of 6, Goettingen No. 387 Airfoil[8] and Wing Loading of 15 Lb. Per Sq. Ft. All Cases Are Assumed as Starting from Level Flight at Constant Throttle. Symbols Are Explained in a Box on P. 159

### Advantages of Angle of Attack

Whether it results from a maneuver[5] or a gust[6], a change in angle may be assumed, for most practical purposes, to be instantaneous. This assumption is convenient in comparing the angle of attack with air-speed and rate of climb. The effect of pulling back on the stick to hold a constant angle of attack is shown in Fig. 1, and that of a constant upward gust is shown in Fig. 2, both being computed for the rather moderate load factor[7] of 1.5. In these two diagrams the comparison is made for the straight or smooth-flow portion of the lift curve. In Fig. 3, a change in angle resulting from the same gust is carried just to the burble point[8].

The air-speed meter itself has comparatively little lag; but there is a large actual lag, relative to the angle of attack, because of the time that is taken for the speed to change, as shown in Fig. 1, while the conditions in Figs. 2 and 3 are such that there is no appreciable speed change. The principal value of the climb indicator seems to lie in the quicker and more certain response in vertical movement of the airplane, for a given change in vertical force, which induces a more satisfactory response of the instrument even though the instrument itself has considerable lag[9]. The actual lag in relation to the angle of attack is large, therefore, with either instrument.

For the conditions of Fig. 3, air-speed and rate of climb are virtually worthless as control references. If conditions beyond the burble point are similarly plotted, it will be found that the small changes of air-speed and rate of climb are definitely misleading, as both dictate a movement of the stick in the wrong direction for recovery. The difficulties are greatly increased by any unusual circumstance such as sudden stoppage of the engine or low visibility. It should be noted that, for Figs. 2 and 3, the airplane is assumed to be held level by reference to the natural horizon or a gyroscope. With or without such aid, the airplane is almost certain to do some pitching of its own, the effects of which would be superimposed on those of the gust.

The load factor $N$ is a rather fundamental item in flight analysis and has been suggested as a primary reference for longitudinal control. The trouble with this is that, for a given airplane in the normal control range, $N$ is a function of speed as well as of angle of attack; or, more specifically

$$N \propto V^2 \alpha_0$$

This clearly means that the airplane can progressively and insidiously get entirely out of hand with respect to either $V$ or $\alpha$, while $N$ shows perfectly constant until the stage is reached at which the pilot must resort to an extreme maneuver as, for example, to avoid falling into a spin or to recover from a steep dive. Hence, in the practical case, the load factor is more effectively controlled by reference to the angle of attack than by reference to the load factor itself.

The same reasoning similarly shows the ambiguity of a direct speed reading, for

$$V \propto \sqrt{(N/\alpha_0)}$$

[5] See Joseph S. Newell's paper, S.A.E. JOURNAL (TRANSACTIONS), January, 1932, p. 31.

[6] See Richard V. Rhode's paper, S.A.E. JOURNAL, September, 1931, p. 179.

[7] See British Aeronautical Research Committee Reports and Memoranda, No. 1392, Acceleration on Aircraft During Maneuvers, by Finn and Nutt.

[8] See National Advisory Committee for Aeronautics Technical Report No. 352, Large Scale Aerodynamic Characteristics of Airfoils, by Jacobs and Anderson.

[9] See Aircraft Instruments, by Herbert N. Eaton and associates, pp. 50 and 51; Ronald Press Co., New York City, 1926.

[10] See British Aeronautical Research Committee Reports and Memoranda, No. 1367, Longitudinal Control and Stability when Stalled.

[11] See Applied Aerodynamics, by L. Barstow, p. 89; Longmans, Green & Co., New York City, 1920.

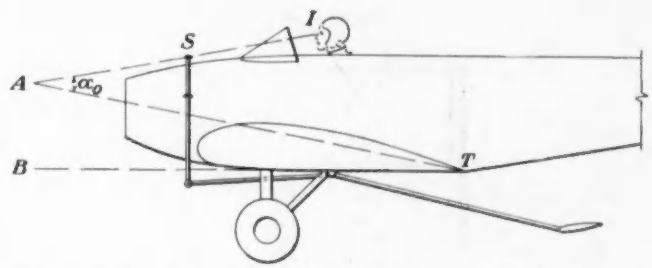



FIG. 4—MECHANICAL TYPE OF LONGITUDINAL INDICATOR

The Indicated Line of Sight $ISA$ Shows the Direction of Motion through the Air, $TA$ Is the Zero Lift Line and $\alpha_0$ Is the True Angle of Attack. The Angle between $BT$, the Conventional Cord Line, and $AI$ *Is the Conventional Angle of Attack* $\alpha$

On the same basis, the corresponding expression for angle of attack,

$$\alpha_0 \propto N/V^2$$

shows a safe reference, because if $\alpha$ is held constant,

$$N \propto V^2$$

Any change of $N$ limits the change of $V$, and therefore of itself, in either direction. For example, if $V$ is increasing, the corresponding increase in $N$ sets up an added drag and turns the flight path relatively upward, which soon stops the process. The reverse also holds, as long as $\alpha$ is held constant.

### Methods of Determining Angle of Attack

Assuming that angle of attack is by far the best single reference for longitudinal control, the problem becomes one of choosing ways and means to make it available to the pilot.

Solutions proposed from time to time have included various supplementary stall-warning devices.

Jones and Alston[10] even suggested an indicator for stalled flight based on the actual position of the control stick, which could be made to give angle of attack in a steady maneuver for a given load distribution and stabilizer setting; but a more direct-reading instrument would certainly be preferable for other conditions, especially if it is to cover the entire flight range.

Probably the most direct-acting device is a vane mechanism such as is shown in Fig. 4, which was tested as one of the early experiments in this study. The movement of the sight bar, actuated by this vane, was so proportioned to the angle of attack that the pilot's line of sight across the bar was, itself, the direction of motion of the airplane through the air.

This principle of indicating the direction of motion was reverted to later in the development of the final instrument. The mechanical vane, although successful from a scientific standpoint, had serious practical disadvantages. It was cumbersome, introduced an appreciable drag and complicated the problem of securing a lateral reading from the same instrument. As considerable interference effects from the wing had to be taken into account in any case, the idea of utilizing directly the air flow around the wing became increasingly attractive. As this is most conveniently done by a liquid-type instrument, we must now consider some of the important qualities inherent in an instrument of this type.

### Liquid-Type Air-Speed Meter

A liquid-type air-speed meter is nothing new, and L. Bairstow[11] has pointed out its special quality of reading relative angle of attack in rough air. We proceed now to prove the more general case applying to a liquid column subjected to any aerodynamic pressure differ-

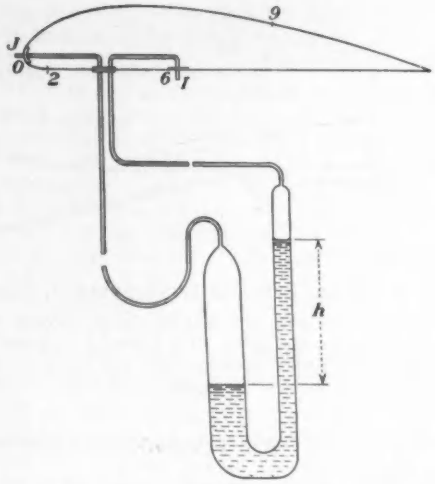



FIG. 5—GENERAL DIAGRAM OF LIQUID LONGITUDINAL INDICATOR

*I* and *J* Are Orifice Members, and 0, 2, 6 and 9 Refer to Orifice Positions[13]

ence, whether directly resulting from speed, angle of attack, or a combination of the two.

Fig. 5 shows a liquid column approximately perpendicular to the path of flight and in equilibrium, acted upon by the force of gravity and an equivalent aerodynamic pressure difference between orifices *J* and *I*. The orifices can be in any form or longitudinal position near the plane of symmetry of the airplane. For conditions not involving acceleration, the pressure difference $P_0$ may of course be expressed in terms of the difference in column height $h/12$. Suppose now that we increase the speed of the airplane from $V_0$ to $V_1$, keeping the angle of attack the same. As all aerodynamic pressures are then increased in the ratio of $V_1^2/V_0^2 = N$, neglecting the effect of thrust and other minor factors, the new pressure difference is

$$P_1 = P_0 \times V_1^2/V_0^2$$

The lift of the wings is also increased in the same ratio; but, as the actual weight *W* remains the same, the difference appears as an inertia force in connection with an upward acceleration. In other words, the weight of the airplane and everything in it appears to be increased in the ratio $V_1^2/V_0^2$. As this includes the liquid in the instrument, the increased difference in pressure merely balances a liquid whose apparent weight is increased in proportion. The same applies to a change in air density or angle of flight path. Therefore *h* remains the same for any one angle of attack, regardless of speed, density or type of maneuver, as long as the total weight carried remains the same. This is equivalent to an angle-of-attack reading, however, only as long as the reading is a single-valued function of the angle of attack itself.

As a first example, suppose the orifices *J* and *I* take the form of the conventional pitot and static heads, substantially out of interference with the wing. Using a liquid of density 0.83, we find the relation between *h*, the initial dynamic pressure $q_0 (= \frac{1}{2}\rho_0 V_0^2)$ and the lift coefficient $C_L (= W/q_0 S)$ to be

$$h = \frac{12 q_0}{62.4 \times 0.83} = \frac{0.232\, W}{C_L S} \qquad (1)$$

For $W/S = 15$, as in Figs. 1, 2 and 3, $h = 3.48/C_L$.

In curve *A*, Fig. 6, *h* is plotted against the angle of attack corresponding to different values of $C_L$ for airfoil G387[13]. This shows that there is an excessive change in reading for a given angular increment at the higher speeds, while for angles approaching the stall the reading first becomes indeterminate and then reverses. The entire curve is also subject to vertical shifting in proportion to changes in *W/S*. Such an instrument therefore is satisfactory only for an intermediate range of values and a fairly constant wing loading.

### Utilizing the Wing-Section Flow

Consider now an orifice of the type shown in Fig. 7, mounted near the wing surface, in which a relative suction is created by the air flow past it in any one direction. If the orifice member is small and there is no pronounced scale effect within the range of operation, such a suction may be put equal to $K \times \rho v^2/2$, where $v$ is the local air velocity in the wing streamline at the point where the orifice member is to be mounted. Now if the wing pressure, at the same point, in the absence of the orifice member, is $p$, the net pressure induced in the orifice tube, when present, is

$$p' = p - K \rho v^2/2$$

But, for any region subject to Bernoulli's Law, which is valid a short distance from the surface around the entire front and bottom,

$$p = q - \rho v^2/2$$

Therefore

$$p' = q - \tfrac{1}{2} \rho v^2 (1 + K) = p\,(1 + K) - Kq \qquad (2)$$

and the difference in pressure between two orifices

$$\Delta p' = \Delta p\,(1 + K)$$

when *K* is the same for both, or

$$\Delta p' = \Delta p + (K_i - K_j) + K_j p_j - K_i p_i \qquad (3)$$

when *K* differs as between the two orifices, or as a

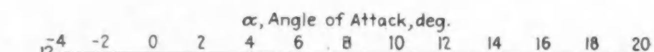



FIG. 6—READING OF LONGITUDINAL INDICATOR

Curves for the Same Airplane Used for Figs. 1, 2, and 3, with Angle of Attack for Orifice Members of Different Types and in Different Positions as Follows: *A*, Pitot Static Head; *B*, *C* and *D*, Orifice Members in Various Positions on the Wing Surface; *E* and *F*, Orifice Members Varied in Suction Effect and Distance From the Wing

[13] See N.A.C.A. Technical Report No. 352, Large Scale Aerodynamic Characteristics of Airfoils, by Jacobs and Anderson.

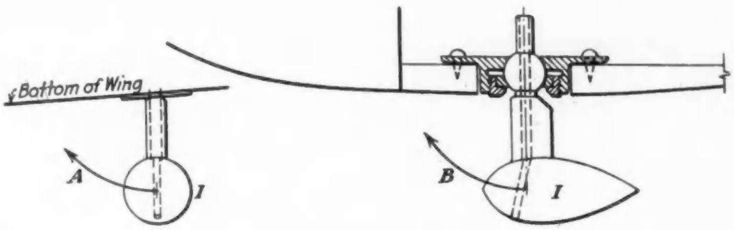



FIG. 7—KNOB-TYPE ORIFICE $I$

A Front View of the Knob in Position Is Shown at the Left and a Side View at the Right. Move in Direction $A$ To Decrease Suction at Low Speed; Move Forward in Direction $B$ To Decrease Suction Near Top Speed

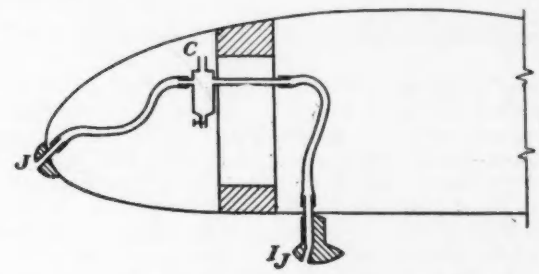



FIG. 8—DIAGRAM OF CENTER-SECTION ORIFICE MEMBERS

$J$ Is the Main Orifice and $I_J$ Is the Adjustable Pressure-Reducing Orifice for High-Speed Airplanes. $C$ Is the Connection to the Reservoir Tube of the Instrument

function of the airflow direction, or both. Values of $K$ for several typical knobs and nozzles are given in Table 1.

Selecting a value of $K = 1$ we get

$$p' = 2p - q$$

and. on the same principle as (1),

$$h = \frac{12 \triangle p' q_0}{62.4 \times 0.83\, q} = 0.232\, q_0 \left(\frac{\triangle p}{q}\right)(1 + K)$$

$$= \frac{0.232\, W}{C_L S}\left(\frac{\triangle p}{q}\right)(1 + K) \qquad (4)$$

For $W/S = 15$ and $K = 1$,

$$h = (6.96/C_L)\ (\triangle p/q)$$

where $\triangle p/q =$ the pressure difference, in terms of $q$, between the two selected points on the airfoil by itself, at any given angle of attack. Curve $B$ in Fig. 6 shows $h$ plotted from Equation (4) using approximately the positions $J$ and $I$ shown on Fig. 5 (orifices 0 and 6 on the section from which data were taken[13]).

Curve $C$ in Fig. 6 is similarly obtained by shifting orifice $J$ to a position half-way between 0 and 2, and curve $D$ is obtained with orifice $J$ in this new position and orifice $I$ shifted to position 9 on top of the wing. Curve $E$ is for orifice $I$ at position 6 and orifice $J$ an infinite distance ahead of the leading edge (actually approximated by a distance of a few feet), also taking from Table 1 $K_i = 1.0$ and $K_j = 0.4$ for plain nozzles at angles of approximately 90 and 0 deg. respectively; which, from Equations (3) and (4), is expressed by the formula

$$h = \frac{0.232\, W}{C_L S}\left(0.6 - \frac{2\, p_i}{q}\right) \qquad (5)$$

The slope of any of these curves can be changed at will by a pressure-reducing orifice member, $I_j$, similar in form and position to member $I$, Fig. 7, connected in parallel with member $J$, Fig. 8.

### Disposing of the Longitudinal Problem

It is thus clear that a great variety of curves can be had merely by a choice of positions. Adding to this a choice of the orifice members themselves, the possibilities of getting almost any effect desired are further increased. The scientifically best method of isolating the effects of the many variables involved is by the mathematical computation of streamline orifice knobs[14], such as are shown in Fig. 7, and Joukowski airfoils[15]. Practical experience, however, has shown nozzles to be more convenient than knobs, and expediency has so far dictated concentration of attention on airfoils in actual use.

Curve $F$, in Fig. 6, obtained with a special type of nozzle described later, illustrates the general type of curve desired. It has substantial negative slope throughout its entire practical range yet does not shoot up too steeply at the smaller angles, and it crosses the zero line at an airfoil angle $\alpha$ of about 9 deg. This last-mentioned condition has a special significance.

Neglecting longitudinal acceleration for the moment, the pressure in the J-tube exactly balances the pressure in the I-tube when $h = 0$. If these aerodynamic pressures balance for any one condition, they will continue to balance for any other condition that keeps $\alpha$ constant. As gravity and inertia are also balanced when $h = 0$, we have for this special case a reading that depends exclusively on angle of attack, independent even of wing loading. The wing-loading factor continues to be of small effect in any case where $h$ is small. Expressed mathematically,

$$h = (W/S) \times f\,(\alpha)$$

for a given wing and orifice arrangement. Then, if $f(\alpha) \approx 0$, $h \approx 0$ and it makes little difference what the value of $W/S$ is.

An effect of the thrust that is worth considering here is the additional margin of lift and control that it gives, particularly at angles near the stall. This is roughly compensated for by mounting the reservoir tube slightly in advance of the other, as shown in Fig. 5. Then, as the stalling position under full power is with the nose well up above the horizontal, the longitudinal gravity component induces a slightly higher reading of the liquid than in the case of a no-power stall. Also, in case of a sudden change in longitudinal force such as results from stoppage of the propeller, the resultant deceleration or acceleration induces an immediate reaction of the liquid in the right direction. With the construction shown in Fig. 5, the indication of the instrument is based on angle of attack; but a scale, if any is provided, need not read in terms of angle. As far as direct flight control is concerned, the only value of a scale is to have something on which to hang experience and judgment with respect to different maneuvers and conditions. If the scale is graduated in terms of level-flight speed, reading from the rear tube only, accuracy is of no importance except for navigation purposes. In case accuracy is desired in the normal cruising range, the scale is graduated by calibration against the tested capabilities of the airplane, using a corrected air-speed meter, ground-speed tests or computed performance in a similar way to the calibration of air-speed meters[16]. Subsequent scales for all similar installations in airplanes of the same type are then the

[13] See N.A.C.A. Technical Report No. 288, Pressure Distribution Over a Rectangular Monoplane Wing Model, by Knight and Loeser.

[14] See Application of Practical Hydrodynamics to Airship Design, by Upson and Klikoff; N.A.C.A. Report, to be issued.

[15] See British Aeronautical Research Committee Reports and Memoranda No. 1106, The Theoretical Pressure Distribution Around Joukowski Airfoils, by W. G. A. Perring.

[16] See N.A.C.A. Technical Report No. 371, Present Status of Aircraft Instruments, Subcommittee on Instruments.

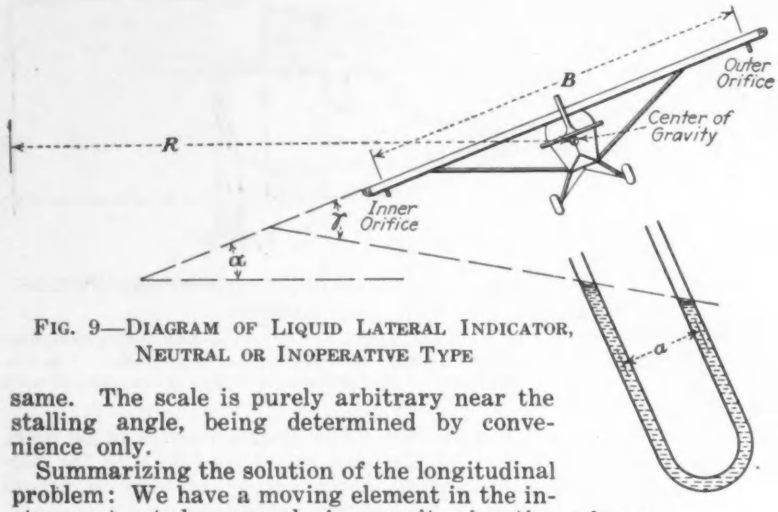



FIG. 9—DIAGRAM OF LIQUID LATERAL INDICATOR, NEUTRAL OR INOPERATIVE TYPE

same. The scale is purely arbitrary near the stalling angle, being determined by convenience only.

Summarizing the solution of the longitudinal problem: We have a moving element in the instrument acted upon only by gravity, inertia and aerodynamic force. These are combined in suitable proportion in the instrument to give a picture of the air in its angle-of-attack relation to the airplane. The same principle will now be extended to show the lateral-attitude relation as well.

### The Lateral Problem

Imagine a glass U-tube containing a liquid, as in Fig. 9, mounted in a plane transverse to the fuselage. If left free, the liquid in the two legs of the tube will by gravity alone seek a common level for all conditions not involving a turn or lateral acceleration. In a turn, the same liquid is subjected to a centrifugal or inertia force, whose lateral component for a perfect bank exactly neutralizes the gravity component. A lateral "aerodynamic horizon" can then be obtained if we oppose the inertia component with an equal aerodynamic force due to the same turning movement. This can be done by utilizing the fact that the outer wing in a turn has greater speed than the inner wing.

It is futile, however, to use the direct dynamic pressure of the air at the two wing tips. Suppose this to be tried, as indicated diagrammatically in Fig. 9, each leg of the U-tube being connected to the nearer wing-tip orifice. Then

$$v_1 = V/R\,[R - (B/2)\cos\beta]$$
$$v_2 = V/R\,[R + (B/2)\cos\beta]$$

Difference of pressure in the two impact orifices equals

$$\rho\, v_2^2/2 - \rho\, v_1^2/2 = (\rho\, v^2\, B/R)\cos\beta$$

But the air in the pressure tubes themselves has mass and is subject to a centrifugal force producing a pressure in the opposite direction. This pressure, per unit cross-section of tube, equals

$$-\,mV^2/R = -\,(\rho\, V^2 B/R)\cos\beta$$

Difference in static pressure resulting from difference in height of the orifices is not included, because the weight of the contained air is balanced by its own buoyancy. We get then exactly zero as the net effective pressure difference at all angles. This neutral result has been checked experimentally and found to be in accord with theory.

### Utilizing the Wing-Tip Flow

Let us now turn to suction orifices similar in principle to those already referred to for the longitudinal indicator. They would be located one near each wing tip, at a position on the section to be determined by further analysis. The connecting tubes will now have to be crossed at the U-tube, instead of connecting directly as in the foregoing. Then, for a turn in a horizontal plane at any angle of bank $\beta$, we have the following forces acting on a unit cross-section of the liquid, those tending to raise the inner column being considered positive:

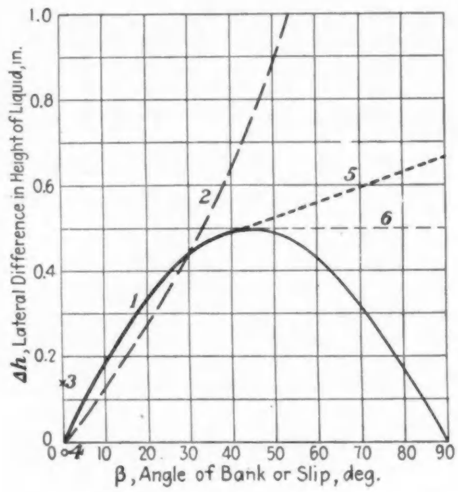



FIG. 10—READING OF LATERAL INDICATOR WITH CROSSED CONNECTIONS

Curve No. 1 Represents a Perfect Bank with Horizontal Radius, Not Attainable in Practice at the Higher Values of $B$. Curve No. 2 Represents a Straight Slip. Curve No. 3 Is for a Level Turning Skid at Constant Speed for $F/W = 1/\sqrt{3}$. Curve No. 4 Is for a Level Non-Turning Skid for the Same Value of $F/W$. Curve No. 5 Is a Modification of Curve No. 1 To Include a Turn in a Vertical Plane for $\beta > 40$ Deg. Curve No. 6 Is a Modification of Curve No. 1 To Include a Slip for $\beta > 45$ Deg.

Gravity:

$$P_g = -\frac{0.83 \times 62.4\, a}{12 \cos\gamma}\sin(\gamma - \beta)$$

Inertia of Liquid:

$$P_{il} = -\frac{0.83 \times 62.4\, a\, V^2}{12\, g\, R\cos\gamma}\cos(\gamma - \beta)$$

Inertia of Air:

$$P_{ia} = \frac{\rho\, B\, v^2}{R}\cos\beta = \frac{2\, q\, B}{R}\cos\beta$$

Aerodynamic Suction Difference, from (2) and (6):

$$P_a = \frac{K\rho}{2}(v_2^2 - v_1^2) - \frac{p}{V^2}(1 + K)(v_2^2 - v_1^2)$$
$$= \frac{B}{R}[K\rho\, V^2] - 2\, p\,(1 + K)]\cos\beta$$

For $K = 1$

$$P_a = \frac{2\, q\, B}{R}\left(1 - \frac{2\, p}{q}\right)\cos\beta$$

Summing up the four parts to zero, we get

$$P = P_g + P_{il} + P_{ia} + P_a = 0$$

or

$$\frac{2\, B\, q\cos\beta}{R}(1 + K)\left(1 - \frac{p}{q}\right) - 4.31\, a\Big[\sin(\gamma - \beta) - \frac{2\, q}{32.2\,\rho\, R}\cos(\gamma - \beta)\Big] = 0 \qquad (7)$$

This general equation must now be narrowed down to a practical range of conditions.

For the instrument to serve as a horizon, there must be a fairly close and definite relation between $\gamma$ and $\beta$. Suppose then that $\gamma = \beta = \pi/6$ for a typical banking angle of 30 deg. Substituting in Equation (5), $R$ and $q$ are both cancelled out and we get immediately

$$a = 5.6\,\rho\, B\,(1 + K)\,[1 - (p/q)] \qquad (8)$$

and for $\rho = 0.00238$ and $K = 1$, $a = B\,[1 - (p/q)]/37.5$. This simple result shows clearly that, if $p/q$ can be held substantially constant, the reliability of the reading at the angle chosen is entirely unaffected by speed or

radius of turn. The same can be shown to apply to any condition that makes $\gamma \approx \beta$.

For further analysis, three limiting sets of conditions are now of interest:

(1) A perfect bank, in which $R = 2\,q/(g\,\rho \tan \beta)$
(2) A straight slip, in which $R = \infty$
(3) A flat skidding turn, in which $\beta = 0$

Also the more general cases of

(4) A non-turning skid
(5) A turn not in a horizontal plane
(6) Combined turning and slipping (or skidding)

### Lateral Readings for Various Conditions

Putting $p/q = 0.3$, for an orifice approximately in position 6 (Fig. 5), and substituting in Equation (7) the value of $R$ for a perfect bank, as given in the above item (1), and the value of $B/a$ from Equation (8), we get, by trigonometric reduction, the difference in height between the liquid columns

$$\triangle h/a = \tan \gamma = 2/3 \sin 2\beta \qquad (9)$$

For values of $\beta$ up to 45 deg., $\triangle h$ is plotted as curve 1 in Fig. 10 based on $a = 3/4$ in. and $B = 40$ ft.

Similarly, substituting $R = \infty$, for a straight slip, we get

$$\triangle h/a = \tan \gamma \tan \beta$$

which is plotted as curve 2 on the same chart.

For a skidding turn, where $\beta = 0$, from Equations (7) and (8),

$$\triangle h/a = \tan \gamma = V^2/100\,R$$

or, in terms of the ratio of centrifugal force to weight, as

$$F/W = V^2/gR$$
$$\Delta h/a = 0.322\,F/W$$

Thus, for a rate of turn equivalent to a bank of 30 deg., which as a *skid* is hardly possible to maintain in practice, taking $a = 3/4$ in., as in the foregoing

$$\triangle h = 0.322 \times 0.75/\sqrt{3} = 0.14$$

compared to 0.44 in. for the same turn properly banked.

Thus far we have been assuming steady conditions with respect to the velocity $V$, the radius $R$ and the angle $\beta$. In a skid, however, all three of these parameters are almost certain to be changing. If $V$, for example, varies while the airplane is in a yawed condition, it results in a component of lateral acceleration that is not directly due to turning.

For a complete understanding of this condition, we must distinguish in Equation (7) between the terms $P_{ia}$ and $P_a$. In the centrifugal action hitherto considered, both terms are effective in opposing the inertial force of the liquid. $P_a$, however, is obviously effective only in turning, whereas $P_{ia}$ is effective for any form of lateral inertia component such as that due to a sudden side gust. The difference between a turning skid and a straight skid or yaw is shown by points 3 and 4 in Fig. 10. The practical case is almost always a composite of the two and will read close to neutral on the instrument, unless modified by a manual adjustment which will be described later.

The turn has hitherto been assumed to be in a horizontal plane, but it can be in any plane. As an extreme case, take a "perfect" vertical bank: Referring to Fig. 10, we see that the theoretical curve 1 for a perfect bank comes back to 0 for $\beta = 90$ deg. This is apparently an impossible condition, from Equation (9), because it would involve either an infinite speed or zero radius. The bank indicator can always be balanced up however by a simultaneous component of turn in a vertical plane. For $\beta = 90$ deg., this requires a downward acceleration of $g = V^2/R_z$ where $R_z$ is the vertical radius of turn. Substituting in Equation (7), with the axis of $\beta$ rotated 90 deg.:

$$P' = P'_{ia} + P'_a = g\,\rho\,B\,(1 + K)\,[1 - (p/q)]$$

$P'_g$ and $P'_{il}$ balance each other by the above assumption. Then, from Equation (8) and the same principles used in Equation (1)

$$\triangle h/a = P'_g\,R/4.31\,aV^2 = 1.33/N \qquad (10)$$

where $N$ = load factor $= F/W = V^2/gR$. Thus the reading in a perfect vertical bank is inversely proportional to the load factor, the latter, in the absence of a coordinated longitudinal reference, depending largely on the personal equation of the pilot. Assuming $N = 1.5$, the same as for the examples of longitudinal control, we get for $\beta = 90$ deg. a value of $\triangle h$ 33 per cent greater than for 45 deg. Considering the arbitrary value assumed for $N$ and the greater facility of approaching the theoretical conditions at lower angles, the 90-deg. value in Fig. 10 has simply been joined to

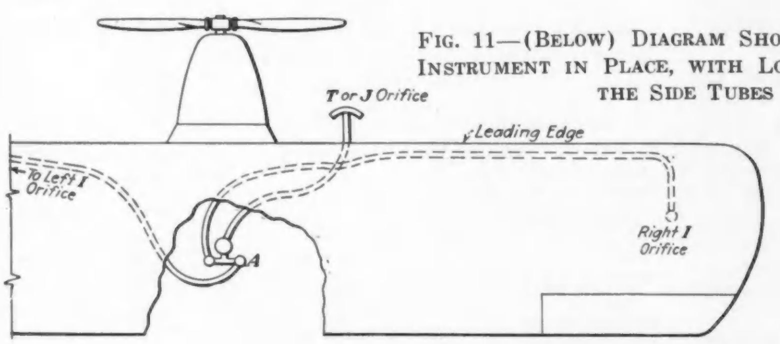
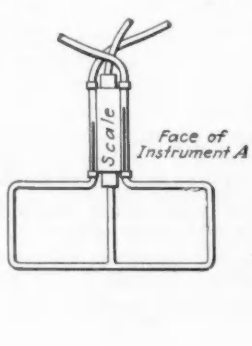



Fig. 11—(Below) Diagram Showing Air-I-Zon Instrument in Place, with Loop Connecting the Side Tubes



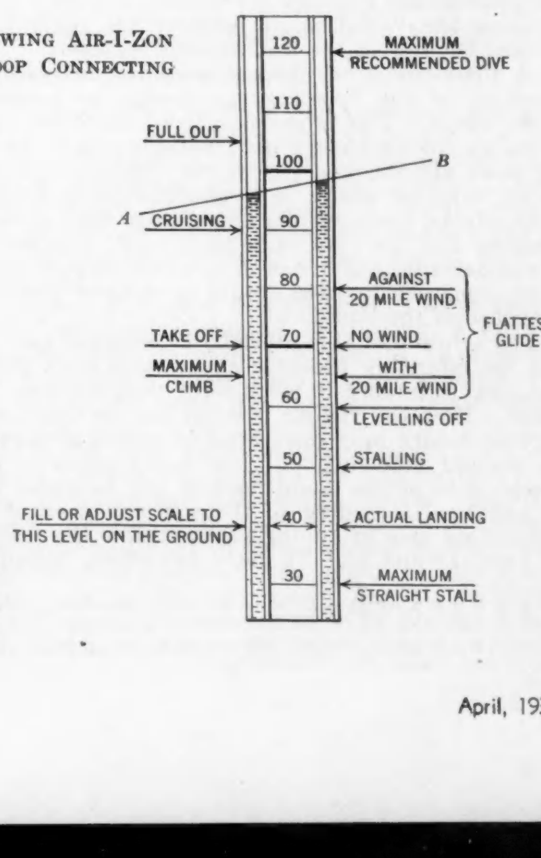




Fig. 12—(Right) Air-I-Zon Scale as Applied to Stout Sky Car

The Aerodynamic Horizon or Air-I-Zon Line *AB* Is an Imaginary Line across the Tops of the Two Small Columns of Liquid. Use It as You Would the Natural Horizon; for Example Right Column High Means Right Wing Low, Both Columns High Means Nose Down, and Vice Versa. The Figures on the Scale Approximate Miles per Hour but More Accurately Represent Airflow Conditions According to the Above Chart (for This Airplane Fully Loaded at Approximately Sea-Level Conditions). For All Ordinary Flying, *Keep within the Heavy Lines*

curve No. 1 by a tangential straight line 5, to conform with the results of practical experience.

A so-called vertical bank may also represent a combination of a horizontal turn and a vertical slip, in which $P_{ia}$ and $P_a$ are nil, and we get

$$\Delta\, h/a = W/F = 1/N$$

where $N$ is the load factor normal to the wing span. Line 6, Fig. 10, represents a maximum of $N = 1.5$, or a resultant load factor of 1.8, for $\beta = 90$ deg., and similarly connected to curve No. 1. This is equivalent, incidentally, to a load factor of 2 for the previous case of an apparently perfect bank. Any more complete discussion of load factors must involve the consideration of lateral and longitudinal readings in combination.

## Combined Lateral and Longitudinal Problem

If now we introduce a third leg to the lateral U-tube, between and slightly in front of the other two, as shown diagrammatically at $A$ in Fig. 11, we can get longitudinal as well as lateral indications on the same instrument. The lateral readings are given by the difference between the two outer columns and the longitudinal by the average height of the same two columns, as shown in Figs. 12 and 13. The two wing-tip orifices both take suction, and the leading-edge orifice, located near the center section, takes either pressure or suction according to the speed and angle of attack of the plane.

Figs. 11 and 14 show nozzle members of types developed from a series of wind-tunnel and flight tests. The I-members under the wing-tips are essentially plain, straight tubes with two-way angular adjustment, and the leading-edge member is either a J with a reverse hook or a T with a double hook. The T-nozzle is used singly on single-engine planes; and the J-nozzle is used in pairs connected in parallel, one unit on each side of the center section, for multi-engine planes.

Good results can be had with either the knobs shown in Figs. 7 and 8 or the nozzles shown in Fig. 14, within a considerable range of different proportions and positions. Fortunately, it seems to be unnecessary to compromise the type or position of the wing-tip members to serve both the lateral and longitudinal requirements to the best advantage. These members are preferably placed to operate at nearly constant pressure as far as longitudinal pitching movements are concerned, thus making the variation of longitudinal reading depend almost entirely on the leading-edge member.

A little variation in local pressure, however, at the position of the I-nozzles can hardly be avoided with most wings. This is principally in the direction of increasing the pressure under the influence of an up-gust or down aileron, and vice-versa. Assuming the nozzle to be mounted where it is almost equally sensitive to both effects, there results a noticeable lag in the lateral reading for the case of a quick roll, because the induced pressure difference in this one respect is momentarily opposite to what would be desired for a correct response of the liquid.

The solution of this difficulty is obtained by considering the offending pressure as being a small portion of the total difference in wing force that produces the roll itself. Now the rolling moment due to this force difference means only one thing in practical flight; that is, angular acceleration. The direct effect of angular acceleration on the liquid reading may be either positive or negative, according to the size and position of the connecting loop of tubing shown below the instrument in Figs. 11 and 15. To get a net effect, including the orifice-pressure difference, of any desired value, it is only necessary to porportion the loop by conventional physics in accordance with the wing loading and the approximate lateral moment of inertia of the airplane[17]. The approximate formula for most jobs is: Loop area, in square inches = 10 $W/S$. Accuracy here is of no importance, on account of the very short time element involved[18]. Longitudinal lag can be decreased by similar means, but this has not yet been found necessary.

## Adjustment Effected

Other variables between different airplanes and installations require somewhat closer attention, which will now be considered.

Adjustment of the T or J nozzles shown in Figs. 11 and 14 is necessary for most new-type planes to get the desired range of readings for different wing sections and approximate loadings. The principal advantage of the nozzles over the knobs is that this adjustment ordinarily can be made simply by controlling the position of the orifice relative to the leading edge, without requiring any separate pressure-reducing orifice. The average curve of readings is approximated by $F$ in Fig. 6, the orifice being usually between 1 and 2 in. from the leading edge.

The most basic lateral variable is the span. The theoretical examples have been based on an assumed ratio of $a$ to $B$ as in Equation (8); but considerable variation does no harm, particularly if it is in the direction of greater total indicator movement, as that can be compensated by the slip adjustment, which will be described.

The lateral balance of the columns in straight, level flight depends fundamentally on the general symmetry of the airplane. In practice, however, owing to the sensitive character of the lateral pressure reading, it has been found difficult to get the orifice members exactly alike. Even when they are alike, a difference in the character of the wing surface is likely to throw the result slightly out of symmetry. It has been found feasible to attain this symmetry of action, both with respect to the numerical value of the suction at some one speed and the rate of increase for variable speed of the wing tip, by simple, straightforward adjust-

TABLE 1—SELECTED VALUES OF $K$ IN FORMULA FOR ORIFICE PRESSURE[a]

| Orifice Member | Angle of Major Axis to Wind Stream[b] (degrees) | $K$ | Source of Data |
|---|---|---|---|
| Single Venturi (Zahm) | 0 | 5.35 | Experimental[c] |
| Double Venturi (Badin) | 0 | 14.+ | |
| 2:1 Ellipsoidal Knob, Orifice at Maximum Section | ± 10 | 0.44 | Theoretical computation, checked by experiment[d] |
| | 0 | 0.46 | |
| Same, with Orifice Half-Way to Nose | —20 | 0.58 | |
| | —10 | 0.51 | |
| | 0 | 0.37 | |
| Straight Nozzle, ⅜-In. Outside Diameter, Open at End | 180 | —1 | Pitot theory |
| | 100 | 0.92 | Small wind-tunnel of Automotive Fan and Bearing Co. 40 m.p.h. |
| | 90 | 1.07 | |
| | 80 | 0.81 | |
| Curved Nozzle of the Same Size, End Bent 165 Deg. on 1-In. Radius | 90 | 0.96 | |
| | 80 | 1.02 | |
| | 60 | 0.87 | |
| | 30 | 0.45 | |
| | 0 | 0.37 | |

[a] $p' - p = -K\rho v^2/2$, where $p' - p$ is the pressure difference due to the reaction of the local air velocity $v$ on the orifice member.

[b] Zero angle indicates main axis of the orifice member parallel to the air stream, with nose of knob or open end of nozzle down stream. Rotation of bent nozzle is in a plane at right angles to the plane of the hook, and the hook is up stream (to bring the opening down stream) for zero angle.

[c] See Aircraft Instruments, by Herbert N. Eaton and associates, p. 74; Ronald Press Co., New York City, 1926.

[d] See Application of Practical Hydrodynamics to Airship Design, by Upson and Klikoff; N.A.C.A. Report to be issued.

[17] See N.A.C.A. Technical Note No. 375, Moments of Inertia of Several Airplanes, by Miller and Soule.

[18] See N.A.C.A. Technical Memorandum No. 615, A Study of Curvilinear Flight, by Helmuth Kruse.

ments. The amplitude of the reading for a slip and/or a turn can also be varied by similar means.

The basis for this lateral adjustment is the fact that the orifice coefficient, $K$, Table 1, for either knobs or nozzles, varies with change in the air-flow angle. The air-flow direction in a vertical plane is determined almost exclusively by the adjacent wing surface. However, the direction of flow under the wing tips in a horizontal plane varies with angle of attack $\alpha$, being at a greater outward angle as $\alpha$ increases, in accordance with accepted airfoil theory. This angle is of course superimposed on any one-way angle due to slip or skid. The setting of two suitable orifice members for which the variation of $K$ is known is a matter of the following routine:

(1) For maximum turn indication, set both nozzles or knobs near to the angle of maximum $K$ for mean air direction at the desired speed.

(2) To correct lateral balance, make a similar or opposite change in $K$ for only one member.

(3) For increasing the slip indication, turn the two members in opposite directions so that the maximum $K$ is for an air-flow direction at a more outward angle.

Actual rules for setting a given type of orifice member are more specific, as indicated in Fig. 7.

The adjustment for side slip, like that for speed, is only for use on a new type of airplane. Its purpose ordinarily is to compensate the column reading for any serious departure from the mathematically correct value of $a/B$, as already noted; in other words, to supplement gravity, the only force previously considered in a slip, by an aerodynamic force equivalent in effect to correcting $a/B$. In special cases, adjustment to suit peculiarities of control or stability of a type of airplane are advantageous. For example, in a ship requiring an excessive use of the rudder, it would be best to lower curve 2 in relation to curve 1 in Fig. 10.

In every case so far encountered, it has been found best to favor aileron control by keeping curve 2 well up. This is the most natural reaction for a pilot with respect to a horizon type of instrument, and it also has navigational advantages which will appear later. However, the two main curves 1 and 2, in Fig. 10, should preferably be kept near enough together so that the airplane can be led positively back to an even keel by use of the rudder alone, assuming this to be possible from a control standpoint.

To facilitate a preliminary lateral balance, as well as a certain range of longitudinal adjustment, two small valves are provided to connect the lines just above the instrument, as shown in Fig. 16. If either column reads high, for any reason, it can be brought down by slightly opening the valve on that side. The nozzle adjustment can then be made at any time that is convenient.

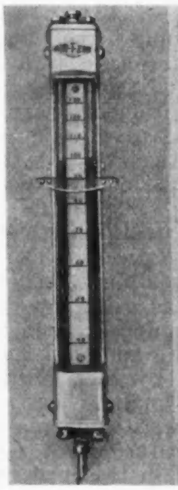


FIG. 13—AIR-I-ZON, WITH ILLUMINATION FOR NIGHT USE

Indicated Position of Liquid Shows Right Wing Slightly Down at Speed Reading of 100 M.P.H.

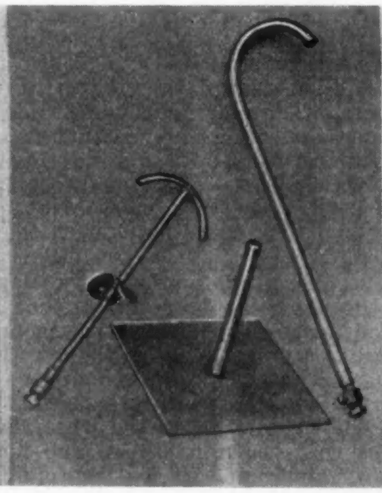


FIG. 14—I, J AND T-TYPE NOZZLES

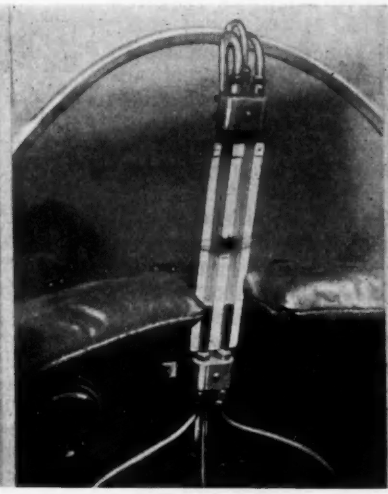


FIG. 15—AIR-I-ZON INSTALLED IN DRIGGS SKYLARK

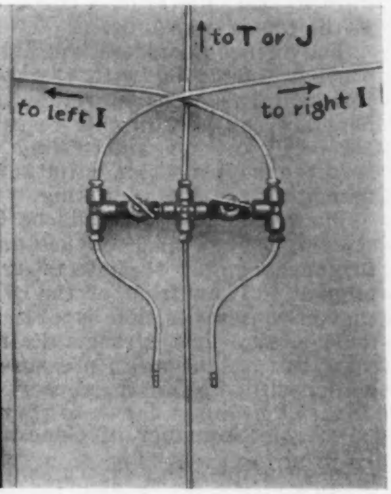



FIG. 16—VALVES FOR FLIGHT ADJUSTMENTS

The Liquid Is in the Position That It Assumes on the Ground. The Scale Is Blank and the Reference Rider Is in the Form of a Small Airplane To Mark the Position of Cruising Speed

Generally speaking, the methods of adjustment described in the foregoing are sufficient for adapting the instrument to any limitations of space or other conditions that may be imposed. However, maximum effectiveness and convenience can be secured in many cases by attention to more fundamental considerations.

### Proportions and Mounting of the Instrument

Each Air-I-Zon after the first has been designed to have a movement of the two side columns commensurate with the actual change in angle of attack, as was the case with the mechanical type previously tested. This results in a rather long instrument, a 7½-in. scale being used at present, but it is believed that the clarity of the reading and the directness of its meaning amply justify this size.

The directness of angular reading also depends upon having the instrument mounted in the pilot's direct line of sight, which in most cases means on a level with the windshield rather than on the instrument board. This might seem like an interference with vision, but practical experience has shown it to be otherwise, as the principal interference with vision is the necessity for the pilot to take his eyes entirely off his course to watch the instruments on the "board." Furthermore, to present any real obstruction to vision, an object must be about as wide as the distance between the observer's eyes. This width is not even approached here, as the instrument for all airplanes except large transports is designed to be 1¼ in. wide, the center distance between the tubes being ¾ in. A

streamlined type is available which can be placed in front of the windshield of planes that cannot accommodate the desired height of instrument within the cabin or cockpit.

The internal dimensions and the type of oil have been chosen to give a desirable amount of viscous damping[19] without destroying the promptness of response. No appreciable evaporation occurs with the light grade of oil that has been found best suited to the purpose.

Most of the instruments thus far made have lacked means to prevent the liquid from being blown out in a steep dive or inverted flight. Contrary to expectations, this has been found a useful feature for private owners, as it discourages unnecessary stunting. For military use, however, a check-valve would be required at the top of each tube.

The orifice members must be fixed in position to prevent tampering with them when their correct adjustment has been determined. The nozzle-type members are the best in this respect and also seem to be absolutely proof against filling with water in flight, as so often happens to a pitot tube. Actual data on ice formation are so far lacking.

The center orifice should be located outside the slipstream, not so much on account of the slipstream as to guard against the effects of a propeller blade stopping directly in front of the orifice. For most planes, the off-center position is of no consequence; but for multi-engine jobs it seems desirable, though not necessary, to take the mean pressure between two positions on opposite sides of the center.

### Summary of General Principles

In principle, the instrument comprises a mass of liquid which is acted upon by gravity, inertia and aerodynamic forces, applied so that, relative to the airplane, the liquid reacts in the opposite direction in response to variation in the aerodynamic forces. These reactions are quantitative in character and in the range of magnitude of the airplane's own angular deflection, both laterally and longitudinally. Thus is established a single control reference of the horizon type, based on the inter-reaction of all the three forces involved.

The resulting instrument is called the Air-I-Zon, to distinguish it from other horizons, as it introduces the aerodynamic element and gives the pilot in effect a continuous picture of the air in relation to the airplane.

The Air-I-Zon has been criticized in theory because it is not directly a turn indicator, excepting in a correct bank. It is not meant to be that, but it does react to a turn in a way that is not ambiguous, thus preventing any tendency to "wind up" into a tighter turn and permitting easy coordination with the compass. This can ordinarily be done by following the Air-I-Zon exclusively with the stick and the compass with the rudder[20]. In a similar way, the new instrument is not directly an air-speed meter, excepting in straight, level flight, but it incorporates the speed reaction as one element in the general problem of safe control.

The theory of the instrument has been outlined in some detail at the risk of making it appear complicated. As a matter of fact, the installation on a new type of plane does involve certain complications of individual analysis. But this is not surprising; rather, it would be unreasonable to hope that a single control instrument could be satisfactory without at least means for adjusting it to fit the proportions and flying characteristics of many different airplanes. The simplicity and effectiveness of the instrument in operation can be appreciated only after flight experience. The part that it plays in almost every flight problem is indicated to some extent by the chart that accompanies the scale of the instrument shown in Fig. 12.

### The "Feel" of an Airplane and Blind Flying

A private pilot, after flying with the Air-I-Zon, made this remark: "It's so easy to fly by that thing, I'd be afraid of getting too dependent on it and losing my sense of feel." This fear is probably groundless if the instrument is properly handled.

Feel is ordinarily a reliable guide in only three ways: the feel of a correct bank, the feel of an excessive load factor, and the feel of the controls. A bank indicator is of help in developing the first mentioned, because it supplies a visual reference that is at first easier to grasp; but still it does not get at the root of the matter, which is the effect on the attitude relative to the air path. The new instrument gives that effect directly, and thus coordinates with the feel of the controls also.

The best training possible in developing feel is to put the plane in a certain attitude as given by the Air-I-Zon and sense the feel that is produced; then to cover the instrument, change the throttle and stick and try to reproduce the same conditions by feel, either with or without the natural horizon, finally checking back to the instrument to see what the attitude really is. Thus both the possibilities and limitations of feel are clearly apparent. It will be found in this process that the bank indicator is no longer necessary, because safe control can be easily maintained by reference to the Air-I-Zon alone. The reason is that a "sloppy" turn does no appreciable harm except in encouraging a transition to an unsafe range of control. But the latter may be due to other causes as well, the results of all of which are given directly by the new instrument.

Blind flying, artificially induced, was successfully accomplished with the first crude Air-I-Zon by a pilot having no previous blind-flying experience. The only reason for added difficulty in the direct control of a plane under such conditions seems to have been the lack of a simple instrument that reacts as a unit to the same set of conditions that affect the airplane itself.

Entirely aside from deliberate blind flying, anyone who flies at all is sometime likely to be caught in local thick weather where safe control in the air and the avoidance of obstructions are simultaneous problems. Perhaps 10 min. is all that is needed in a particular case to make a climbing turn and head out of the thick area, yet how many can do it? It is probably safe to say, without an actual questionnaire, that 95 per cent of all pilots lack either the means or the ability to fly blind[21], for a combination of the following reasons: (*a*) the cost of a set of instruments, (*b*) the difficulty of learning to use them and (*c*) distrust of instruments that read so differently from the customary indications of normal flight. The Air-I-Zon meets these objections so completely that, as found by experience, it is an important asset for all flying. This means that blind conditions, when they come, can be met by an adaptation of methods already in use, without special training for the purpose.

The vertical reading is interpreted mainly from coordination with experience or with the help of a chart such as is shown in Fig. 12. In the ground run, the tail is held up until the *Take Off* reading is reached, when the stick is at once pulled back into a climb and

[19] See N.A.C.A. Technical Report No. 398, Investigation of Damping Liquids for Aircraft Instruments, by Houseman and Keulegan.

[20] For an analogous, but necessarily more complicated, system coordinating the conventional instruments, see Blind or Instrument Flying, by Howard C. Stark; published by the author, Newark, N. J.

[21] For dangers due to the necessity of following many instruments, see *Aviation Engineering*, January, 1930, p. 21.

the liquid held at the same level or higher while pulling out of the field. This gives a slight reserve over the absolute *Maximum Climb* reading.

At the latter position the pilot's line of sight across the tops of the columns is at almost the maximum angle above the natural horizon, excepting in a zoom, but to utilize it fully requires constant attention. Hence the normal flight range begins at the take-off speed, which in this case corresponds with that of flattest glide, and extends to the top of the scale, which is adjusted to the maximum recommended diving speed. In any normal maneuver, all that is necessary for safe control in a direct sense is to keep both columns within these limits, regardless of slipping, skidding, pitching and engine speed.

The same rule applies if the engine should fail at a critical moment[22]. In that case, attention to the instrument is of the very first importance. If necessary, follow the indication of the instrument first and then worry about running into something; but, in practice, the position of the instrument makes it unnecessary ever to lose sight of the terrain if the ship affords generally satisfactory vision.

On attaining the desired altitude, a 5-min. trial determines the correct Air-I-Zon reading for level flight, which thereafter remains the same for equal load, altitude and throttle. It is convenient at first, though not necessary, to set the height of the instrument so that the tops of the columns are on the natural horizon in straight, level flight. The approximate angle of climb or dive for all conditions is then given directly by the mean position of the liquid "Air-I-Zon line" above or below the horizon. Seeing the two principal references in constant relation to each other, the pilot soon appreciates the significance of each; that the natural or geographic horizon is a reference mark from the outside world, while the Air-I-Zon line is a visualization of the air through which he is actually flying.

The latter has of course no direct relation to altitude or actual direction. But altitude is indirectly maintained by control of pitching; and, considering that in a correct bank the ship always turns toward the low wing or high column of liquid, it is easy with a little practice to follow a compass by the method already mentioned, without the further help of a turn-and-bank meter except perhaps in air that is rougher than any in which the instrument has yet been tried.

Upon first acquaintance, the two columns may seem to be moving up and down rather aimlessly. If, instead of thinking of the liquid as moving, the pilot imagines it to be at rest and the airplane to be doing all the moving, the control will be surprisingly smooth. This is especially important in a long glide under conditions in which every foot of distance counts.

### Making the Most of a Glide

The use of the term "glide stretching" as almost synonymous with suicide is a strong reflection on current control methods. The sad part about it, as revealed by the Air-I-Zon, is that a dangerous stall or spin is far removed from any attitude of the plane that is at all conducive to real glide stretching. Speaking more generally, it is notoriously difficult to pick an attainable field at a distance and then glide to it with any assurance. The new instrument is the answer to both phases of this problem, as demonstrated time after time in straight glides from altitudes of 2000 ft. or more under varied wind conditions.

The procedure is simple and direct. The pilot picks his field tentatively; sits back in the seat, as in Fig. 4, with his eyes in a constant position; heads for the field, keeping the Air-I-Zon line steady at *Flattest Glide*, allowing for the probable wind as indicated on the chart, Fig. 12; and watches the field in relation to the tops of the columns of liquid. If the field pulls upward in relation to the columns, he surely will undershoot the mark, and the sooner he gives up that field the better. However, if the field progressively sinks in relation to the Air-I-Zon line, there is altitude to spare. When fully assured of this, altitude can be killed by any of the well-known methods; but common sense dictates saving a substantial margin until in the immediate neighborhood of the field, particularly if it is in any other direction than against the wind. This is to allow for the turn into the field and for probable variations of wind.

Some modern airplanes can be held in a stalled attitude for a straight, steep glide, and this process is facilitated and safeguarded by the Air-I-Zon. The same applies also to the more common maneuvers of slipping and "fishtailing." Unless the plane is specifically designed for landing from a continuous stalled glide, normal gliding conditions must be restored at a proper altitude and the final stalling reserved for the last few feet. Here again the instrument plays its part by developing judgment based on accuracy instead of mere guesswork.

In pulling out from either a steep dive or tight spiral, there is a well-known tendency to over-control of the elevator. This is because any increase in inertia component normal to the span is identified with an immediate increase in the angle of attack and load factor, but not so directly with the speed. For any control to be correct, its direct result must be known; and in this, as in previous examples, the angle of attack is the most direct criterion. In the same way, the principal criterion of what the airplane is doing in any steeply banked turn is the longitudinal reading of the Air-I-Zon, not the lateral. This is as it should be, because a tight turn is primarily a problem of longitudinal or elevator control. The lateral reading is still always in the right direction, however, as shown by Fig. 10; and is the more positive the lower the load factor, as noted in the discussion of Equation (10). But, as already brought out, the load factor itself is best regulated by reference to angle of attack, which brings us back again to the reading of the longitudinal element of the instrument.

Although still lacking an actual test in a spin, it seems obvious from theoretical grounds that a normal spin would induce an exaggerated reading in the direction to indicate the right control movement for recovery. But there is no excuse for getting into a spin at all with this instrument; because, when approaching a spin, the nose is rising relative to the air and is so indicated by the Air-I-Zon, even though it may be falling relative to all other references.

All of this shows that, although the longitudinal and lateral problems may be considered separately for certain purposes of analysis, they cannot be so dissociated in practical flight, and any single flight-control instrument must combine these two essential elements if it is to give complete information about even one of them alone.

### Conclusion

Experience with airplanes of many different types and sizes, as well as theory, now make it clear that the new instrument is fundamentally sound and, subject to detail improvements, thoroughly practical in its application. While the most obvious function of the instrument is in blind flying as usually understood[23], it is expected that it will find a still more important use in

[22] See N.A.C.A. Technical Note No. 363, The Behavior of Conventional Airplanes in Situations Thought To Lead to Most Crashes, by Fred E. Weick.

[23] For an excellent description of instruction methods with present instruments, see Impressions of an Instrument-Flying Course; *The Aeroplane*, Jan. 6, 13 and 20, 1932.

safeguarding ordinary flight control. This is particularly true for novice pilots, to whom all flying is at present more or less blind flying, because they have neither the experience nor any other basis for accurately judging their control movements.

To those who use the time-honored argument against any use of instruments by a novice, I need only reply that, whether we like it or not, the idea of making flight training unnecessarily hard and dangerous is rapidly going out of style. Given instrument equipment that is sufficiently simple, the most logical procedure is to teach instrument flying first and flying without instruments only as a later refinement.

In conclusion, I wish to express my indebtedness to the many interested individuals whose suggestions and encouragement have been of invaluable help.

# Aerial Navigation—Methods and Equipment

*(Concluded from p. 158)*

With observations taken at intervals of 20 or 30 min., ground-speed and drift can be determined rapidly without reference to the earth.

### Correction Watch for Civil Time

To avoid conversion of civil to sidereal time for star work, two second-setting watches are carried, one rated to Greenwich Civil Time for solar and lunar observations and one rated to Greenwich Sidereal Time for use in stellar observations. The sidereal watch is rated to run 3 min. 56.6 sec. per day fast of civil time.

A movement is under way to eliminate the use of sidereal time and to work the stars from civil time. This will simplify navigation considerably. The Nautical Almanac can be changed to make this possible, so that all the elements in the Almanac will be given for civil time for the sun, moon, stars and planets.

The second-setting attachment on the navigation watches invented by Lieutenant-Commander Weems, shown in Fig. 8, enables the second dial to be rotated to eliminate the error without interfering with the internal mechanism of the watch.

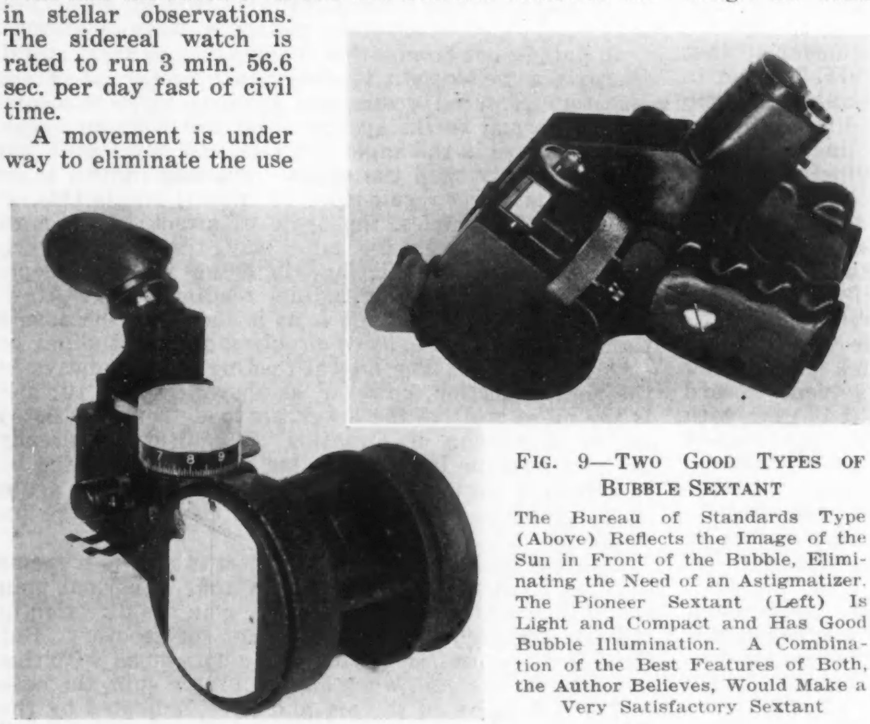


FIG. 9—TWO GOOD TYPES OF BUBBLE SEXTANT

The Bureau of Standards Type (Above) Reflects the Image of the Sun in Front of the Bubble, Eliminating the Need of an Astigmatizer. The Pioneer Sextant (Left) Is Light and Compact and Has Good Bubble Illumination. A Combination of the Best Features of Both, the Author Believes, Would Make a Very Satisfactory Sextant

A completely satisfactory bubble sextant has not yet been developed, and to get very accurate results from instruments of the present types is very difficult. The most that can be expected with present equipment is an accuracy of about five miles under fairly good air conditions. Acceleration or deceleration of the plane and rough air conditions seriously affect the accuracy of the bubble. The writer believes that before long a gyro sextant will be developed which will give us the same accuracy of one mile that is obtainable in the calculations for lines of position.

The Bureau of Standards type of bubble sextant, shown above in Fig. 9, possesses many desirable features. The reflected image of the sun is shown in front of the bubble, eliminating the need of an astigmatizer. For stellar observations, the observer looks directly through a piece of plain glass at the star and brings the reflection of the bubble into alignment. The bubble remains fixed and is affected very little by changes in temperature.

The Pioneer bubble sextant, shown below in Fig. 9, has certain excellent features. The instrument is very compact and light and the method ot bubble illumination is good, but, as the reflection of the observed body is seen behind the bubble, an astigmatizer is necessary. In my opinion an astigmatizer is not desirable in a sextant. A combination of the good features of the Bureau of Standards type and the Pioneer sextant would, I believe, make a very satisfactory instrument. A fixed bubble will be found a decided advantage for actual air navigation, as observations frequently must be obtained on short notice.

With the increasing interest that is being taken in the subject of aerial navigation, we may expect many improvements to be made in the equipment and methods employed.

# The Rational Specification of Airplane Load Factors

## Aeronautic Meeting Paper

By Edward P. Warner[1]

AIRPLANE designing is the only branch of structural engineering making any pretense of strength calculation in which such calculations are based upon a direct empirical assumption or specification of the total forces acting upon specific parts of the structure and, as a rule, having little or no relation to one another. Whether our load factors are sound throughout, no one can be certain. Although the United States Department of Commerce and the British authorities are each satisfied with its own load factors, neither has given an adequate reason for believing its practice to be right. Whereas the American and the British specifications have suggested until recently, and the British regulations still indicate, that weight of the airplane alone determines the maximum loads to which the wing structure is subjected, the author asserts positively that this is not true and that the gross weight may not even be a primary factor.

The putting of specifications on a basis of rational analysis is advocated, and the first requirement is said to be to go back of the loads themselves to the conditions under which they arise, calculating the loads upon any part of the structure from a given condition of flight.

Four conditions of flight or maneuvers are set forth and discussed, formulas for calculation of wing load factors being given and charts presented. Factors of safety are discussed and true factors of safety suggested for different flight conditions.

Conclusions drawn from the investigation are that (*a*), except for airplanes of less than 6000-lb. weight or those having balanced elevator controls, the weight of the airplane is or should be a minor element in determining load factors; (*b*) power loading ranks first in importance for big airplanes; (*c*) wing loading ranks second in large planes, but on machines of less than 4000-lb. gross weight, wing loading, weight and size and shape of the tail surfaces should be preeminent.

AMONG the branches of structural engineering, airplane design occupies a lonely eminence. Of those in which any pretense of strength calculation is made, it is the only one in which the calculations are based upon a direct assumption or specification of the total forces acting upon certain parts of the structure. In the design of bridges, of buildings and even of ships, a set of conditions is assumed and the resultant stresses are traced throughout the structure—so much rolling load and dead load distributed over the bridge, a wind of so many miles an hour, so much snow load per square foot on the roof or the ship subjected to the action of a trochoidal wave of specified length and height. The loads, in any event, derive from first principles.

We have done away with all that in aeronautical engineering. We make certain assumptions about the angle of attack at which the maximum load is to be encountered, but our specifications of the magnitude of the total load to be carried are purely empirical. They derive from no concrete image of the conditions under which the load will fall upon the structure, and, as a consequence, the specifications are written quite independently for each structural element. Instead of assuming a condition of flight and tracing its consequences to the ultimate, in accordance with the standard practice of the civil, mechanical or marine engineer, we set down an arbitrary specification for the wings, another for the fuselage and another for the tail surfaces, and as a rule they have little or nothing to do with one another.

We in America have been major offenders upon those points and especially as regards consistency of practice. Our load factors may be sound throughout; they may avoid any serious hazard of structural failure, and at the same time not be so severe as to force the building of undue weight into the structure. In some respects they certainly excel European practice, but whether they are sound no one can say, except as a consequence of an almost infinite number of detailed experiments on individual aircraft, experiments that are slow, costly and complex in technique and often extremely hazardous. The British rules for stress analysis and those of certain Continental countries, particularly Germany, transgress less seriously against the rules of logic than do our own. In general they are built up on certain assumptions of loading conditions which give corresponding values for the loads simultaneously existing upon all parts of the structure and make possible the analysis of the structure as a whole. In no country, however, has the subject really been pursued far enough back toward first principles. In every country much of arbitrary and empirical specification, such as was undeniably inevitable 15 years ago, remains. By now, however, we should have accumulated enough experience and enough knowledge of the basic theory of aerial flight either to escape these crude expedients entirely or at least to check them against specifications resting solely upon rational principles.

### Wing Load Factors Not Determined by Airplane Weight Alone

The Department of Commerce holds that the high-angle load factor on the wing truss should be 1.3 times as high for an airplane of 2500-lb. weight as for one of 5000 lb. The British assert that the ratio should be 1.1. Each government authority is well satisfied with its own practice, but neither has so far given any adequate reason for supposing that its own practice is right. That load factors are high enough in both countries appears to be indicated by experience and by the virtual absence of structural failures except during violent acrobatics. Whether they are too high, and whether they represent a substantially greater margin of safety in some types and sizes of aircraft than in others, I venture to suggest that no one positively knows. Upon one point, however, we can do more than venture suggestions; we can say with great positiveness that the maximum loads to which the wing structure is subjected are not determined by the weight of the airplane alone, as both the British and American specifica-

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tions would have suggested until very recently and as British regulations still indicate. Perhaps, indeed, the gross weight may not even be a primary factor.

This scolding of current tendencies is, in a certain sense, too tardy to be just. Rational analysis of loading conditions had been conspicuously absent until two or three years ago, particularly in the United States, but since then marked improvements have been made in this respect. Interest was aroused in the subject as the result of discussion by the writer and others at the aeronautic industry's meetings in the City of Washington in September, 1930, preparatory to the annual conference with the Department of Commerce on airworthiness and structural requirements for design. Agreement was reached at that time that the appointment of a joint committee of the industry and the interested Government departments should be sought, so that structural specifications might be generally overhauled and put on a rational basis. No immediate result was forthcoming, and the discussion and the proposal were renewed at the 1931 meeting. Following upon that conference, the Department of Commerce began to take a very active interest and recently it has published several notes on the subject[2]. During the same period a notable contribution[3] to the literature was presented by Prof. Joseph S. Newell, of the Massachusetts Institute of Technology, at the Aeronautic Meeting of the Society in September, 1931.

During the last two years some very interesting work along similar lines has been done in Great Britain and in Germany.

### Loads Calculable from Conditions Creating Them

It has been generally characteristic of these studies that the formulas developed, especially for wing-load factors, have been a mixture of the rational and the empirical and have been "checked" by comparison with the factors required under the existing specifications. Such a comparison is very interesting but is not conclusive, and should be only incidental to the main purpose. It has, or should have, no bearing upon the value of the results of the rational analysis. If the existing specifications are right, trying to develop anything else as an alternative or an improvement is a waste of time. If, on the other hand, they are wrong, the new formulas should not agree with the old ones, and for them to be found in agreement would be a proof of error rather than a proof of merit. However, one type of check which can sometimes be made has a very direct bearing upon the value of a formula or a new method of load determination. If we can secure a list of airplanes that have actually had structural failures and another list of machines that have not, a correct method of load specification obviously would require that those of the first group should have been designed to load factors somewhat higher than were actually used, whereas the machines of the second group should be left undisturbed or may even have their required factors lowered. Only the Army and the Navy have had material with which to make an analysis of that sort, for in the case of commercial aircraft the variability of the maintenance factor plays a large part.

Structural failures may occur, even in machines that are perfectly sound in structural design, as the result of deterioration in service. One interesting analysis of the sort, covering a score of machines, was made in checking a formula developed some years ago[4], but it is now unfortunately somewhat out of date. Moreover, the formula used was largely empirical in its derivation, with very general assumptions on such points as the variation of maneuverability with size of craft.

The first requirement in a rational analysis is, as already indicated, that we should go back of the loads themselves to the conditions under which the loads arise. It is there that our specification really should be set up. Given the condition of flight, the loads upon the wings and upon any other part of the structure are incidental and calculable consequences.

### Maneuvers That Create Severest Loads

The conditions under which an airplane may fly are, of course, infinitely varied. Probably it will be agreed, however, that the severest loads on all elements except the landing-gear are covered by

(1) A straight vertical dive
(2) A sharp pull-up from a dive at high speed
(3) Nosing over sharply while flying at high speed, or diving, as in starting an outside loop
(4) Flying in bumpy air

Spins, rolls and other maneuvers have been omitted, but they are at least of secondary significance. They are of importance for certain elements of the structure, because of the unsymmetrical loading that they impose, and should be considered in that connection.

The four conditions listed are, with one exception, not really conditions of flight, but flight maneuvers. A vertical dive (1) is a specific thing, for which a complete analysis can be made. A sharp pull-up from a dive (2), on the other hand, is many different things in rapid sequence, and a dozen analyses could be made for as many different sets of conditions, ranging from the instant at which the pilot starts to pull the stick back up to the time when the maneuver is completed and normal level flight regained. Further subdivision is needed, thus

(2) A sharp pull-up from a dive at high speed
- (*a*) Condition of maximum loading on the horizontal tail surfaces, usually arising approximately at the instant when the pilot has exerted the maximum force on the stick—from 0.3 to 0.6 sec. after the rearward movement of the stick is started
- (*b*) Condition of maximum wing loading, arising at an instant just before the wings attain the maximum angle of attack reached during a maneuver, or just before reaching the angle of maximum lift, if that angle should be exceeded at any subsequent time. It may be from 0.5 to 3.0 sec. after the rearward movement of the stick is started
- (*c*) Some condition intermediate between (*a*) and (*b*), corresponding to the most severe combined tail load and dynamic load on the fuselage

(3) Nosing over sharply while flying at high speed, or diving, as in starting an outside loop. Subdivisions correspond to those of (2)
- (*a*) Maximum up load on tail
- (*b*) Maximum inverted load on wing
- (*c*) Condition of most severe combined fuselage loading. This usually is unimportant

(4) Flying in bumpy air
- (*a*) Condition of suddenly encountering a rising vertical current of air of maximum possible velocity
- (*b*) Condition of suddenly encountering a descending vertical current of air of maximum possible velocity
- (*c*) Suddenly encountering horizontal gusts of direction opposite to direction of flight. Ordinarily this is unimportant

[2] See *Air Commerce Bulletin*, Nov. 2, and Dec. 1, 1931, and Jan. 15, 1932.

[3] See S.A.E. JOURNAL, January, 1932, p. 31.

[4] See National Advisory Committee for Aeronautics Technical Note No. 263, A Load-Factor Formula, by Roy G. Miller.

### Calculating Loads in a Straight Dive

It is hardly necessary to pause over the straight vertical diving condition, except to write a specification for the speed of dive. Given such a specification, and a wind-tunnel test on the airfoil combination used on the plane, the moment coefficient at zero lift can be read, the moment above the front spar determined and the load on the rear truss very closely approximated by dividing the moment by the distance between the spars. The tail load, similarly, is approximately equal to the diving moment on the wing truss divided by the distance from a point midway between the two wing spars to the tail. The front truss carries a down load equal to the load on the rear truss minus that on the tail. These formulas are only an approximation, as the angle of attack in a vertical dive actually is very slightly different from that of zero lift, a small net lift on the wings being required to balance the down load on the tail. Also, taking moments about a point midway between the spars does not give an exactly correct result. In neither case, however, would the resultant error be more than 2 or 3 per cent, and the exact geometrical method, if wanted, is sufficiently obvious.

The speed of vertical dive to be used in calculation can easily be approximated in terms of the general characteristics of the airplane. It has often been demonstrated that the maximum speed of level flight with full power is equal to $K\sqrt[3]{(P/S)}$, where $K$ is a constant depending on the cleanness of design of the plane, the type of wing section used and various other points; $P$ is the engine power and $S$ is the wing area. In present design practice, $K$ ranges from 130 to 145, exceeding 150 for the very cleanest designs, such as that of the Schneider Trophy winner of 1931. The maximum-speed formula can easily be converted into a dividing-speed formula, for in a vertical dive the weight of the airplane is equivalent to the propeller thrust, and the power exerted is equal to the weight times the diving speed divided by the appropriate power constant. Making the necessary conversions, it develops that the limiting diving speed in miles per hour is

$$V_l = 96\sqrt{(W/S)} \quad (1)$$

based upon a value of 140 for $K$. $W$ and $S$ have their usual significance of gross weight and total wing area.

### Three Stipulations To Be Satisfied

That airplanes of all sizes will be subjected to the condition of vertical dive to terminal velocity is hardly to be expected. At such points as this, pure logic has finally to make a partial abdication in favor of specification from experience. The degree of discretion that the most heavy-handed or most reckless pilot can be expected to display in handling a large plane cannot be ascertained by pure mathematics. As a rule, any machine may conceivably have to be momentarily thrown into the vertical attitude as the result of stress of weather or to dive through a hole in fog; therefore every machine should be designed to stand a vertical dive starting at the maximum speed of horizontal flight and continuing for 3 sec. The speed attained in 3 sec. of diving is low compared with the terminal speed; in all cases it is very nearly 60 m.p.h. above the maximum horizontal-flight speed, and that may be taken as the basis of calculation of the stresses in such a short dive.

The second general stipulation is that every machine should be capable of steady descent at the terminal speed of some very steep glide. Here, again, the factor of judgment must enter, but it is suggested that the required gliding angle on machines not intended for acrobatic flying should be 20 deg. on planes of 12,000-lb. weight or more and increase to 45 deg. on planes of 3000-lb. weight or less. All machines designed for acrobatic service should be able to withstand a vertical dive to terminal velocity.

Quite obviously, from Formula (1) the equilibrium speed in a steep glide is closely approximated by

$$V_l = 96\sqrt{(W \sin\theta/S)} \quad (2)$$

where $\theta$ is the angle of the path to the horizontal. The limiting speed is plotted against the angle of glide for several different wing loadings in Fig. 1. These speeds are, of course, for glides with power off. With the engine running at full throttle, they would be increased about 30 per cent if the gliding speed without power is equal to the maximum flight speed, or 10 to 15 per cent if the gliding speed without power exceeds the maximum level-flight speed by 50 per cent.

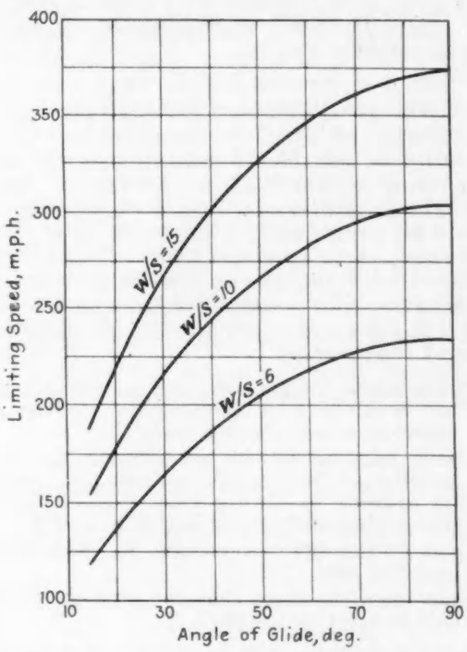


FIG. 1—LIMITING SPEED IN A STEEP GLIDE

These Curves Are for Power Off. The Speed Would Be Increased about 30 Per Cent with Full Power on, If Gliding Speed without Power Is Equal to Maximum Flight Speed, or 10 to 15 Per Cent If It Exceeds the Latter by 50 Per Cent

Finally, the third stipulation is that all machines of all categories should be able to withstand steady flight under full power on a slightly decending path at a speed exceeding level-flight speed by at least 20 per cent. In general, this is the least severe of the three diving conditions for planes of all categories. The second condition, that of the steady steep glide at terminal velocity, is the critical one in most cases. Incidentally, it is closely equivalent to one of the stress-analysis conditions required by the German authorities.

### Pulling Out from a Dive

The analysis for any particular load condition should be carried through the complete structure, but the admirable work of Richard V. Rhode, of the National Advisory Committee for Aeronautics, makes it unnecessary to go into a detailed analysis of the tail loads for each loading condition. I turn, rather, to the analysis of wing loading under another set of circumstances; that is, the enormously more complex case of sudden recovery from a dive.

If we had to reckon only with the maximum load

that theoretically could be imposed in pulling out from a dive with the greatest possible abruptness, our problem would be extremely simple. In practice, however, it has become almost axiomatic that virtually any airplane can be broken by sufficiently severe handling, or at least that the theoretical maximum-load factors in abrupt recovery are far beyond any loads for which any airplane is designed. As a matter of fact, Formula (1) leads to the very curious conclusion that the theoretical maximum loading depends upon only fineness and is virtually the same for all well-designed airplanes, whatever their size, type or wing loading. The classic formula is

$$n = (V_l/V_{min.})^2$$

where $n$ is the load factor and $V_l$ and $V_{min.}$ are respectively the limiting speed of dive and the minimum speed of level flight. The formula for $V_l$ has already been developed. $V_{min.}$ is closely approximated for most airfoil sections in common use by

$$V_{min.} = 17\sqrt{(W/S)}$$

The maximum possible load factor is then $(96/17)^2$, or 32. Obviously, an airplane designed for that factor would hardly be capable of getting into the air at all, to say nothing of carrying a military or commercial load, and the imposition of even a considerably smaller load would be immediately fatal to the pilot.

There must, then, be some limit. Broadly speaking, the possible limitations are in two categories: the physical limits of the pilot or the airplane, and the limits imposed by the pilot's discretion. The physical limits, in turn, are of four classes:

(1) Physiological limitation of the maximum-load factor that the pilot can sustain without losing consciousness or "going black"
(2) Limits imposed by the maneuverability characteristics of the airplane and the time taken for its attitude to change from that of diving to that corresponding to a high-lift coefficient
(3) Limit of rapidity with which the pilot can pull back the stick
(4) Limit upon the force that the pilot is physically able to exert on the stick

The factors of discretion may be considered as corresponding to (3) and (4). The pilot's good sense and experience may make him pull the stick back comparatively slowly when coming out of a fast dive, especially with a heavy machine, or they may caution him to ease off a little when he finds the force on the stick getting very large, although it may still be well within his physical capacity. The second factor ordinarily is the one that comes into play.

### Factor of Pilot's Physical Limitations

We cannot disregard the pilot's judgment as a factor in alleviating the loads on the structure, but the absolute physical limitations, which can be dealt with on purely rational lines, should be disposed of first. With a theoretical maximum-load factor of 32 in all cases, how large a factor could actually be attained in an airplane of typical characteristics and by a pilot of normal strength?

The effect of maneuverability characteristics is the easiest with which to reckon. When an airplane is pulled out of a dive, assuming the pilot's strength to be unlimited, the effect of pulling up the elevator is to give a stalling moment of the magnitude

$$M = L_{tc}S_tl_tV^2 \qquad (3)$$

with the resultant angular acceleration

$$d\omega/dt = (L_{tc}S_tl_tV^2) \,/\, (Wgk_B{}^2) \qquad (4)$$

where

$k_B$ = radius of gyration of the plane around the transverse axis
$L_{tc}$ = change of lift coefficient on tail
$l_t$ = distance from center of gravity of the plane to center of pressure of the tail
$S_t$ = horizontal tail area

Roughly speaking, since $k_B$ and $l_t$ vary in about the same ratio in a typical design, the angular acceleration is inversely proportional to the linear dimension of the airplane for a constant wing loading. It is more nearly accurate to say that it is inversely proportional to a linear dimension, inversely proportional to the wing loading and directly proportional to the ratio of horizontal tail-surface area to wing area.

The maximum angular velocity that can be attained during the process of pulling out from a dive is determined by the balance between the control moment and the damping moment. The former varies, as just shown, in proportion to the fuselage length and the square of the speed. The damping moment, on the other hand, is proportional to the square of the fuselage length and to the first power of the speed. The maximum angular velocity then increases with speed, unlike the angular acceleration, which is practically independent of that quantity, but they are alike in being inversely proportional to a linear dimension of the aircraft.

The time required to pull the plane up from the diving attitude to an angle of attack corresponding to maximum lift, assuming the pilot to be possessed of infinite strength or the controls to be perfectly balanced, would then vary approximately directly as a linear dimension of the plane. For a constant wing loading, it would vary approximately as the square root of the weight. The loss of speed from the speed of vertical dive to that at the instant of reaching the angle of maximum lift would approximately follow the same rule.

An exhaustive analysis by the step-by-step method[5] made by H. Bolas and G. A. Allward has indicated that the most abrupt possible use of the controls would bring a typical plane of 3600-lb. weight up to the angle of maximum lift from a steep dive with a loss of speed of approximately 4 per cent during the change of attitude. This is approximately in accordance with the results of tests made by the National Advisory Committee for Aeronautics and by Major J. H. Doolittle and others. The loss of speed would be approximately inversely proportional to the initial angular acceleration and to the maximum obtainable angular velocity. It would, in other words, be proportional to the square root of the weight divided by the square root of the wing loading.

On a plane of 3000-lb. weight, the maximum load actually attainable by the most abrupt use of the controls is approximately 0.93 of the "theoretical maximum" already discussed. On a plane of 12,000-lb. weight, with normal tail-surface area and wing loading, the corresponding ratio would be 0.85. However, as even this would permit of a load factor of 27 in recovering from a terminal vertical dive, we must look farther unless we are to depend exclusively upon the physiological and the discretionary factors in setting our load specifications.

The most important factor, undoubtedly, is the limit of the pilot's strength. Over a wide range, at least up to one-half the "theoretical maximum" load factor, the load imposed upon the wing structure is almost directly proportional to the force used on the stick in pulling out. Bolas and Allward, in the paper already referred to, have investigated this point in some detail.

### Formula for Recovery from a Dive

Properly to complete the study of which this paper is only an outline, the making of a great number of step-by-step calculations for airplanes of various sizes and

[5] See British Aeronautical Research Committee Reports and Memoranda No. 1229, Loads on the Main Planes and Tail of an Aeroplane When Recovering from a Dive.

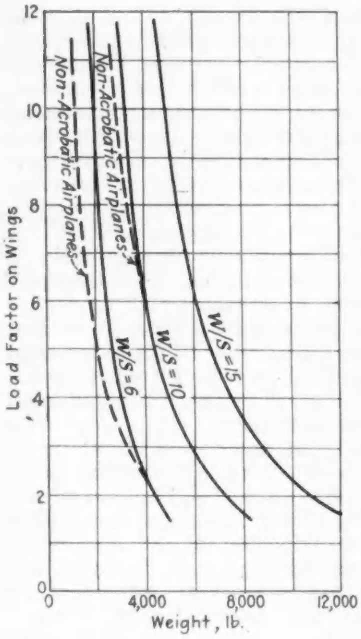


**FIG. 2—LOAD FACTOR ON WINGS IN RECOVERY FROM A VERTICAL DIVE WITH 100-LB. FORCE ON THE STICK**

The Drop in Load Factor with Increase in Weight Is Startling. The Curves Are Based on the Assumption That the Area of the Horizontal Tail Surfaces Is 15 Per Cent of Wing Area, the Aspect Ratio of Tail Is 4, the Ratio of Fuselage Length to Square Root of Wing Area Is Normal and That Elevator Control Is Unbalanced. These Relations Are Likely To Be Different in Large Airplanes

characteristics would be desirable. Lacking that, much can be done by approximation, especially with the assistance of a further research[6] performed in England, as reported by F. B. Gates and H. B. Howard, who, for the particular case of recovery from a vertical dive, have been able to intergrate the equations of motion directly and to develop a formula approximately equal to

$$n = 250\,P/E\,l_t\,(S_t)^{3/2}$$

where

$E$ = ratio of the elevator chord to the combined chord of elevator and stabilizer
$l_t$ = distance from center of pressure of the tail to center of gravity of the airplane
$P$ = maximum load applied to the stick
$n$ = load factor
$S_t$ = tail area, where the tail surfaces have an aspect ratio of 4.

If $E$ be taken as one-third, which is typical practice; if the tail area is 15 per cent of the wing area, $l_t$ is one-half of the over-all span and the aspect ratio of the airplane wing equal to 6, the formula reduces by obvious transformation to $n = 10{,}200P/S^2$, $S$ being the wing area.

The formula applies only for airplanes of neutral longitudinal stability. Positive stability decreases the load factor attainable, but stability depends so much upon weight distribution that it is unsafe to count on anything more than neutral characteristics when calculating structural loads.

The apparent load factors for a 100-lb. force on the stick are then as plotted in Fig. 2. Incidentally, it is worthy of note that the speed from which the pull-out is started makes no difference in these factors except that it must be high enough so that the "theoretical maximum" load factor will be considerably larger than the factor given by the Gates-Howard formula. The method breaks down if the angle of attack reached during the recovery is very near the angle of maximum lift. The basic assumptions call for a vertical dive, but the factors experienced in pulling up from a steep glide are very much the same.

The drop in load factor with increasing weight is very startling. It has no apparent relation to the conventional form of load-factor specification curve but is what we should expect, not only from the formula resulting from the intricate mathematical research of Messrs. Gates and Howard, but also from the most commonplace consideration of the fundamental equation of motion. With a constant force exerted on the stick, an approximately constant control moment obviously is developed about the center of gravity of the airplane. The angular acceleration is then inversely proportional to the weight of the airplane and the square of a linear dimension, or, for a constant wing loading, to the square of the wing area. Still more important is the fact that the maximum velocity attainable for a constant moment imposed by the controls is inversely proportional to the product of the tail-surface area and the square of the length.

Fig. 2 was based upon certain definite assumptions and cannot be fully accepted unless those assumptions remain valid. It is good only in the event that the area of the horizontal tail surfaces is 15 per cent of the wing area, that the aspect ratio of the tail is 4, that the ratio of length of fuselage to the square foot of the wing area is normal (there is relatively little variation in that respect among normal designs) and that the elevator control is unbalanced. Large airplanes are likely to have somewhat smaller tail surfaces in proportion to the wings and of higher aspect ratio than are small ones and are more likely to have balanced elevators. All of these factors increase the potential wing loads in recovering from a dive with a given force on the stick.

## Reducing Tail Area Increases Wing Loads

That reducing the relative area of the tail surfaces should increase the rapidity of recovery from a dive and

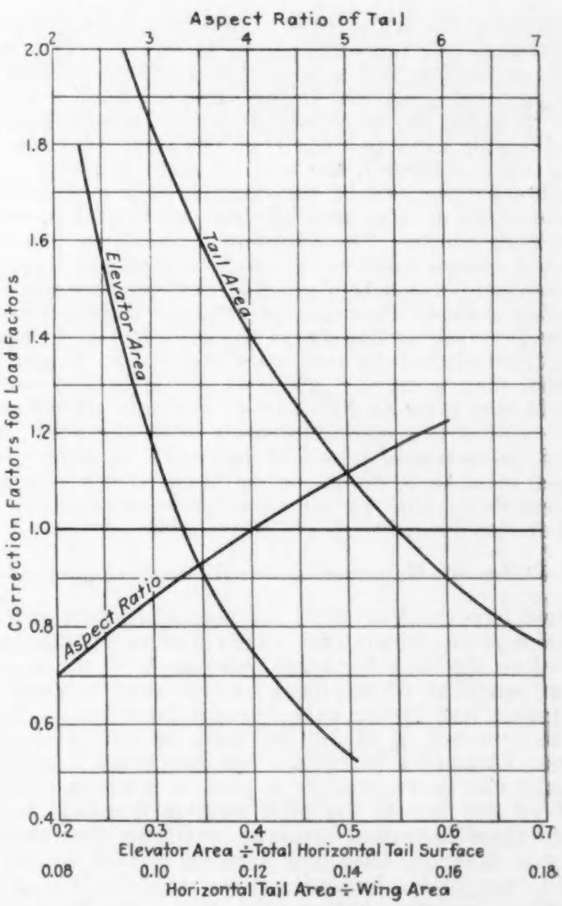


**FIG. 3—CORRECTION FACTORS FOR MODIFYING LOAD-FACTOR CURVES OF FIG. 2**

[6] See British Aeronautical Research Committee Reports and Memoranda No. 1232, On the Maximum Load in Pulling Out from Vertical Dives.

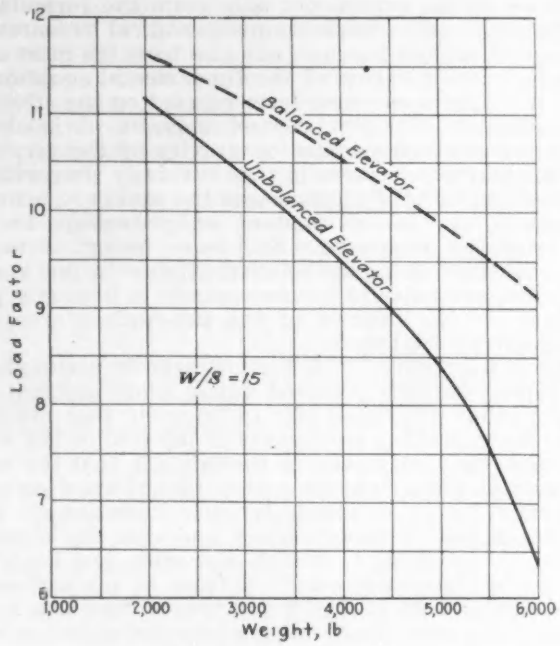


FIG. 4—PREDICTED WING LOAD FACTORS FOR BALANCED AND UNBALANCED ELEVATOR

The Pilot's Ability To Exert Stick Force Is Assumed To Decrease from 100 Lb. at a Load Factor of 8 to 0 at a Factor of 12. The Unbalanced Elevator Has 20 Per Cent of Its Area Forward of the Hinge

so increase the wing loads is, at first sight, somewhat surprising, but the explanation is simple. If a given airplane having two sets of tail surfaces of different size be considered, and if the same stick force be used in both cases, the small elevators can be pulled up to a considerably greater angle than the large ones; in fact, as already indicated, the total moment imposed on the airplane by the use of the controls will be practically independent of the area of the tail surfaces, within very wide limits. The damping moment, on the other hand, is proportional to tail-surface area and therefore, for a given plane with a given stick force, the maximum angular velocity that can be attained during recovery varies inversely as the size of the stabilizer and elevator.

If the tail-surface area were reduced to 12 per cent of the wing area, the effect would be to increase the load factors given in Fig. 2 by 40 per cent. If the aspect ratio of the tail were increased to 5, the load factor would be increased about 15 per cent. A drop of tail aspect ratio to 3, on the other hand, which is a more conventional value for small airplanes, would cut the load factor down by about 15 per cent.

### Effect of Balanced Control Most Important

Most important of all is the potential effect of a balanced control, which may easily reduce the force required on the stick for large movements of the elevator by as much as 60 per cent and thereby increase the attainable load factor with a given force by 2½ times.

The assumption of 100 lb. force on the stick is, of course, entirely arbitrary. The maximum force that actually can be exerted by a pilot of average strength is about 200 lb. If the pilot were deliberately setting out to break a typical airplane, or if his discretion be entirely ignored, the load factors plotted in Fig. 2 would have to be doubled. However, I believe that it is safe to presume that no pilot who is not deliberately trying to wreck a machine will exceed a 100-lb. stick force. That force is large enough so that its application will require a very definite conscious effort, and little danger exists of its being exceeded in a moment of excitement or alarm without the pilot's realizing that the danger line has been approached. The stick force for smaller planes can be reduced, if only because their cockpit accommodations generally are more crowded and application of large forces is not as easy. I suggest that keeping it at 100 lb. for all airplanes fitted for acrobatic flying and for all airplanes of any class of 4000-lb. weight or more is reasonable. For airplanes below that weight, I believe it is reasonable to reduce the stick force linearly to 40 lb. with a 1000-lb. weight or less. Such a modification of the stick-force assumption would change the form of the curve in Fig. 2 for the non-acrobatic airplanes, as shown by the dash lines at the left of the solid-line curves.

A further suggestion is that the values taken from the curves in Fig. 2 be modified for ratio of tail area to wing area, for aspect ratio of tail surfaces and for ratio of elevator to stabilizer chord, in accordance with the correction factors plotted in Fig. 3, and that when the elevator is balanced the load factors be increased by a percentage equal to five times the proportion of the total elevator area that lies forward of the hinge. Thus, with 20 per cent of the area forward of the elevator hinge, the possible load factors would have to be doubled. This may seem to give preposterously high factors, but it is a very important point. Not only the theory, but practical experience, support it. A large proportion of the airplanes, both large and small, upon which structural failures have occurred have been machines having balanced elevators and tail surfaces somewhat smaller in proportion to the wings than is the customary practice.

### Influence of the Physiological Factor

The physiological factor has so far been neglected in this analysis. It does not operate as an absolute barrier to the imposition of very high load factors, but it has an important influence. Plenty of experience has been accumulated, especially during the tests made by the National Advisory Committee for Aeronautics, to show that even a brief instant of submission to a load factor of more than 8 will seriously impair a pilot's efficiency. Undoubtedly a safe assumption is that at very high load factors at least some falling off will occur in the force that the pilot will exert on the stick. I believe that it is most reasonable to start this decrease in stick force at a factor of 8, and to assume that the maximum force the pilot will exert will fall linearly from 100 lb. at that point to zero at a factor of 12. One of the curves in Fig. 2 has been redrawn in Fig. 4, with due allowance for that assumption of reduced stick-force. The solid line shows the predicted load factors with unbalanced controls, the dash lines with 20 per cent of the elevator area forward of the hinge. Of all the assumptions so far made, this is the one about which I feel most uncertain. It may be that the assumed drop in force is too rapid.

### Conditions Encountered in Bumpy Air

Passing over the other dive conditions, so that the investigation of high-angle load factors on the wing structure may be completed, we turn to the conditions encountered in bumpy air. Richard V. Rhode has investigated these in some detail.[7]. The classic formula for the load factor developed when an airplane in normal flight suddenly strikes an ascending current of air is

$$n = 1 + vV_a\,(dL_c/da)/(W/S) \qquad (4)$$

[7] See S.A.E. JOURNAL, September, 1931, p. 179.

where $V$ is the speed of flight, $v$ is the vertical speed of the air current, both in miles per hour, and the other quantities have their classic significance. The lift coefficient is given in "engineering units", not involving the air density.

Obviously, any airplane must be able to fly through rough air at maximum speed. The time may come when instruments to indicate the magnitude of bumps will be fitted and pilots will be expected to slow down when striking rough air, but that time certainly is rather remote; for the present we must reckon with flying straight through the worst bumps that can be encountered.

The question of the maximum velocity of vertical currents is one for the meteorologist rather than the aeronautic engineer to determine, but Mr. Rhode and other members of the staff of the National Advisory Committee for Aeronautics have derived considerable information by working backward from accelerometer records taken in flying airplanes of known characteristics through bumps. The general conclusion, which checks in a general way with what has been discovered directly by the students of aerography, is that the maximum vertical velocity likely to be encountered in anything like normal weather conditions is about 30 ft. per sec. Under extreme conditions, such as those of a violent hail-storm or of a line squall or thunder-storm of great force, the vertical velocities may reach 100 ft. per sec. A bump of such magnitude as that will in every case have the effect of momentarily increasing the effective angle of attack to and beyond the angle of maximum lift of the airfoil. To be safe under such conditions, it is necessary that the machine be designed to withstand the full theoretical load resulting from an instantaneous pull-up from a dive at a speed equal to the maximum speed in level flight.

For present-day transport airplanes, even of very large size, the speed-range ratio is from 2 to 3, and the necessary load factor would therefore range from 4 to 9. This factor has nothing whatever to do with the maneuverability or control power of the airplane. Nor has it anything to do with the weight. We have no reason for supposing that the load factors on large airplanes in extremely rough air are appreciably smaller than those on light planes. To be sure, slight differences exist because a large machine is less likely to be struck by a gust on every unit of area of its wing structure at the same instant, and because of the possible yielding of the wings of a large plane, especially in a cantilever type. They may possibly relieve the load by 10 to 20 per cent in some cases, but they are dangerous factors upon which to rely in our present state of ignorance of atmospheric structure.

Equation (4) can easily be transformed, if it be assumed that the airplane is flying at its maximum speed and is of average design characteristics, so that the formula already given for maximum speed can be used. The load-factor formula, taking 0.01 as the standard average value for $dL_c/d\alpha$, then becomes

$$n = 1 + 1.4\, v \sqrt[3]{[(P/S)/(W/S)]}$$

If the vertical velocity of the air current encountered be assumed to be 20 m.p.h., this reduces to

$$n = 1 + 28/\sqrt[3]{[(W/P)\ (W/S)^2]}$$

If, on the other hand, the possible velocity of the vertical current that may be encountered at maximum speed be assumed to have virtually no limit, the formula must be based on the absolute speed range of the airplane, and then becomes

$$n = 68/[W/P \sqrt{(W/S)}]^{2/3}$$

The load factors determined on the two assumptions are plotted in Fig. 5.

The fact will be noted that all of the factors so far plotted relate to loads that might actually be expected to exist, and that nothing has been said about true factors of safety. The factor of safety is, of course, designed to take care of unsuspected flaws in construction and also of deterioration in service. Usually it is somewhat larger than it appears to be, for most severe loads on airplane structures are applied for only a very brief interval of time. The structure is calculated for loads to be carried steadily for an indefinite period and actually will sustain loads appreciably greater than those, if they are quickly applied and as quickly removed. The matter deserves much more investigation than it has had, but for the present it is well simply to bear it in mind as adding something to the factor of safety upon which we can depend. In the usual case the effect probably amounts to an increase of about 10 per cent in the reserve strength of an airplane under such suddenly applied loads as those existing when striking a bump or being pulled from a dive.

### Reserve Strength under Sudden Loads

The factors of safety should, of course, be highest for those loads which are likely to be most frequently experienced, and they can approach unity for conditions which are so abnormal that they are likely to afflict only a very few airplanes at any time during their useful life. Specifically, I suggest that the true factor of safety should be 1.25 for the most severe recoveries from dives, or that the factors plotted in Figs. 2 and 4 should be increased by 25 per cent to furnish design data. The factor of safety for ordinary bumpy air—the conditions to which Fig. 5 relate—should be 1.5; and for the most extreme line-squall conditions, such as are also plotted in Fig. 5, should be reduced to 1.0. The line-squall condition is, in almost every case, the most severe.

In determining the high-angle load factor for which wings should be designed, it remains only to choose the most severe condition among all those specified. That can be done by drawing separate curves for each case. The general indication from all this investigation is that, except for airplanes of less than 6000-lb. weight

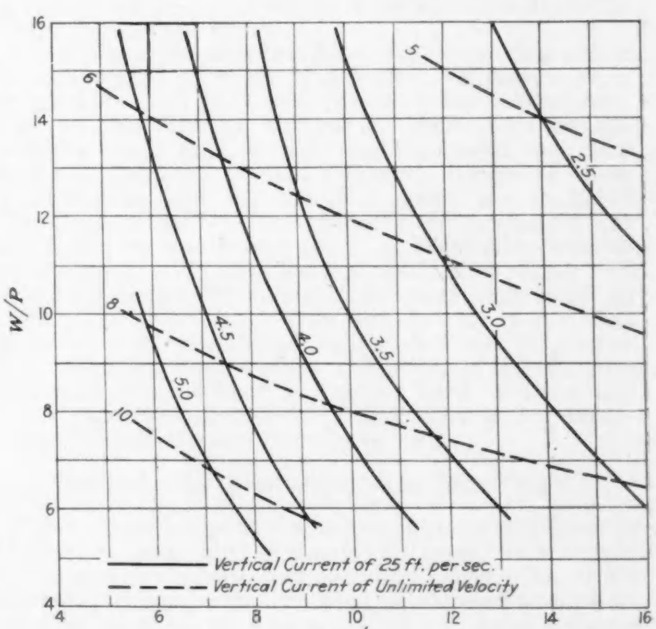


**FIG. 5—WING LOAD FACTORS FOR AIRPLANE ENCOUNTERING VERTICAL AIR CURRENTS**

The Airplane Is Assumed To Have Customary Design Characteristics, To Be Flying at Maximum Speed, and To Encounter a Vertical Current Having a Velocity of 25 Ft. per Sec. and One of Unlimited Velocity

or those having balanced elevator controls, the weight of the plane is or should be a minor element in determining high-angle load factors. Power loading ranks first in importance for the big ships, and in that respect the changes in specification recently made by the Department of Commerce certainly represent a move in the right direction. Wing loading ranks second in importance on large planes but, on machines of less than 4000-lb. gross weight, wing loading, weight and the size and shape of the tail surfaces should be preeminent.

### Low-Angle Load Factors

Similar investigation should, of course, be made for low-angle load factors, and very much the same process can be followed. It will be found that, for typical distribution of the structural members in the wing truss, the maximum load on the rear truss for large machines is likely to be encountered in bumpy air of the "normal" type, for which it has been suggested that a true factor of safety of 1.5 should be allowed. For example, a machine flying at 150 m.p.h. and having a wing loading of 12 lb. per sq. ft. will undergo a momentary change of true angle of attack of 8 deg. if a vertical current of 20-m.p.h. velocity is encountered. The factor on the machine as a whole under those conditions is 3.5, but the load on the rear truss alone is only about 1.4 times as high as in normal flight at maximum speed. With a factor of safety of 1.5 included, the load factor needed in the high-speed analysis would rise to 2.1. Without carrying all this study through in detail for the low-angle conditions, or, more accurately speaking, for the conditions most severe on the rear truss, the general indication is that load factors on the rear truss in large planes have been higher than they should be in proportion to those on the front truss. On small planes, on the other hand, the rear-truss factors have not, as a rule, been high enough.

In the recovery from a dive, loads on the rear truss change comparatively slowly with changing angle of attack. They can best be specified in terms of the load that the truss carries in steady dive at the maximum diving speed that is required for the type, as already defined. If an airplane is pulled up instantly from the diving attitude to the angle of attack of maximum lift, the loads on the rear truss are, on the average, about 2.8 times as high as those during the steady dive. It is suggested, then, that this ratio be taken as the factor of specification and that it be increased linearly from 1.5 for airplanes of 12,000-lb. weight up to 2.4 for those of 4000-lb. weight or less. This system of specification would break down, and require special modification, only when the airfoil section used is of "stable" form, with an upturned trailing edge.

Lack of space and time unfortunately prevents an exhaustive survey of fuselage and tail-surface loads or of those on the landing-gear. In connection with the fuselage, however, one particular word of caution should be said. Special pains should be taken to insure that the loads provided are really consistent and can really coexist. It was for many years, and still is in some quarters, the regular practice to specify a certain tail load on the fuselage and a certain dynamic load, without any reference whatever to the effect of the angular acceleration which the tail load will inevitably produce. (Recent Department of Commerce rules show a great improvement in that respect.) It is absolutely impossible that maximum tail load and maximum dynamic load should ever coincide, and to draw up any specification which permits them to do so is fully as absurd as to specify the maximum normal load on the upper wing of a biplane at the same time as the maximum inverted load exists on the lower. The very fact that there is a large load on the tail surfaces of an airplane operates, in itself, to relieve the dynamic load on the fuselage, especially in the rearmost bays.

# Constants and Variables in Production and Production Men

Production Meeting Address

By Louis Ruthenburg[1]

APPARENTLY certain well-defined constants appear in and control events during periods of subnormal business activity; but, admittedly, the behavior of a given industry may be decidedly variable in the presence of given general conditions. The behavior of the automobile industry is not the same today as it was in 1921. The resiliency of this great industry in our last period of seriously subnormal general business astonished all of us. Now, it seems to lack that buoyancy. We need not seek far for the reason; to put our finger on this particular variable is rather easy.

In 1920, with approximately 24,000,000 families resident in the United States, about 8,250,000 passenger-cars were registered. In 1930, with a little less than 30,000,000 families living here, more than 23,000,000 cars were registered. A definite law of growth controls the industry. First there was a period of years during which growth was relatively slow. Then came a period of rapid growth, which was maintained until the market was initially satisfied. Finally, there is a period of slower growth-rate that is dependent upon replacements and incidental market expansion. The automobile industry was obviously in that intermediate phase of rapid growth in 1920. In 1931 it is just as definitely in the third phase of relatively slow growth. Resiliency in the face of subnormal general business is a characteristic of the rapid-growth period. Synchronism with the general business curve is one of the penalties exacted of a mature industry.

### Prepare for Prosperity

But, "Sweet are the uses of adversity." The automobile has a short replacement cycle. Sales have been below normal replacement levels for many months. A tremendous market is in the making for those who can capture it. Now is the time to prepare for prosperity.

In preparation for prosperity, the production man must play an exacting rôle. How tremendously the demands made upon the production man have increased! The production man who thinks today that he has made great progress will look back five years from now and observe that, as of October, 1931, he "hadn't been nowhere and he hadn't seen nothing." We must become "sales-minded," because the automobile business has for 20 years been becoming a sales problem rather than a production problem. Once we could sell anything we could make; now we certainly can make anything we can sell.

A wise friend of mine observed recently that the man in the engine room of a ship never has the same point of view as the officer on the bridge. Some such difference in viewpoint exists between the production executive and the sales executive. You in the engine room are likely to get many queer-sounding signals during the next few years; but, if you were on the bridge and could constantly watch the sea ahead and the compass and the chart, you probably would be passing some hectic signals to the engine-room yourselves.

The designing engineers are cooking up some nice things for us. Just about the time we have a new job processed and costs are coming into line, they will pass a lot of bright new ideas into the shop. That will not be unusual, but the chances are that their ideas will be more radical and more frequent than formerly.

C. F. Kettering has said many times that the way to get people to buy new things is to make them dissatisfied with the old. Of course, he is right. Did not his electric starter obsolete every car in existence? Fifteen years after its introduction, the annual sales of passenger-cars had increased more than 800 per cent.

Last Sunday I sat between two engineers who represent two of the larger automotive groups; and if they release to production a very small percentage of the things they were talking about—well, production men, get on your toes!

Every clear-thinking production executive will look forward with a most receptive attitude toward sales-stimulating innovations. The new 1932 models certainly appear to approach dangerously close to perfection, but it is not unlikely that in 1942 we shall realize that, while we were thinking so largely in terms of "gadgets," we were building our automobiles "wrong end to." Why do we sweat and strain to gain that last 5 m.p.h. at the expense of bigger engines and added cylinders when a streamline body might add 15 or 20 per cent to top speed by merely eliminating that terrific vacuum behind the body?

Is it not possible that the American car-buying public will decree that it wants true streamline design, with the vibration and heat and fumes of the engine relegated to the rear of the car? These peculiar appendages called fenders and running-boards may find their way into the discard. If such things as these *should* happen, how will the 1932 models look in 1942?

To the end that we may be ready and proficient, our manufacturing equipment must be reasonably flexible and adaptable. We have learned that lesson rather well since 1919, when we thought we could crystallize an entire plant around a current design, only to find that the design was obsolete before the plant was in production. We know now that inflexible, single-purpose equipment may be more a liability than an asset and that a reasonable degree of adaptability is not inconsistent with minimum production costs.

### Demands the Production Man Must Meet

The automotive production man always will have to meet three inexorable demands: to meet the schedule, to improve the quality and to reduce costs. All of his effective business activities must be directed toward accomplishing these objectives. It seems quite probable that, in preparation for prosperity, his attack upon these objectives will be from certain angles not fully exploited heretofore.

No production man would contend that all of our productive and non-productive positions are filled by entirely competent people. Many enlightened production men will admit that a measurable increase of ef-

[1] M.S.A.E.—President, general manager, Copeland Products, Inc., Mount Clemens, Mich.

ficiency might result from more consistent and more comprehensive training. Possibly we shall deal more effectively with industrial education during the next few years than we have done in the past. We have demonstrated repeatedly the futility of leaving this important function to the personnel director, who cannot, in the nature of things, have the most effective contact for accomplishing the optimum results. Consistent, continuous training of apprentices, productive workers, clerical workers, job setters, foremen and their assistants will bring about more satisfactory performance in respect to meeting schedules, improving the production and reducing costs. And this will be distinctly the production man's job.

Not only must our people be trained in the technical aspects of their jobs; they must be trained in such a way as to appreciate the viewpoint and the necessities of all departments of the business with which they come in contact. Our foremen can no longer be merely the master mechanics of their departments; they must become departmental general managers, and that means that, in addition to knowing the technical elements of their job, they must understand the economic and human aspects.

Having been trained as shop men and engineers, are we not likely to give more thought to technical matters than to the economic and human phases of our responsibilities? We are rather sure of our constants and variables in technical matters. What of the constants and variables involved in our economic and human equations? Surely the shop-trained men and the engineer should, by virtue of their training, be able to comprehend the application of certain fundamental laws which control economic movements and human relationships far better than do men trained in other fields.

### Physical Laws Apply to Human Action

Certain fundamental relationships exist in this world that cannot be repealed or amended by legislation. These relationships have existed since time began and will continue to control all activity until time shall cease. There is the law of action and reaction, which is simply expressed by the statement that "Every action is followed by an equal and oppositely directed reaction." This is no more a law of dynamics, in the exclusive sense, than it is a law of human relationships or monetary relationships. It is universal and eternal in its application.

Unfair treatment of labor by management is followed by retaliatory measures on the part of labor. Depressions follow boom periods just as headaches follow sprees. Intolerance, as expressed in prohibition, is followed by intemperance and law-breaking. In politics, the reactionaries always follow the liberals. Too much Bourbonism is followed by too much democracy. Most of us believe in the validity of the Golden Rule. Is not the Golden Rule an inferential expression of the law of action and reaction?

A certain formula in elementary dynamics deals with the vibrations of a spring in its return to a state of rest after it has been released from stress. An understanding of this principle will shed a great deal of light upon the current world depression, the boom of 1923-1929, the depression of 1920-1921 and the boom of 1919. The whole fabric of the world was tremendously stressed as a result of the World War, and conditions may reasonably be expected to oscillate from abnormal to subnormal until that stress has spent itself or the oscillations have been modified by other forces.

Then there is the law of diminishing return which usually is claimed by the economists as one of their laws. It is no more a law of economics in the exclusive sense than it is a law of dynamics or human behavior. The first savage who observed that he expended disproportionately more energy to run 8 m.p.h. than he used in walking 4 m.p.h. was conscious of the law of diminishing return. It operates in all fields of activity, and knowledge of its operation clarifies many otherwise involved problems in monetary matters and human relationships.

### Static Wealth a Cause of Depression

Another of the very fundamental dynamic laws has to do with energy being the product of mass and velocity. The student of elementary dynamics will recognize the formula $1/2MV^2$ as a fundamental energy relationship. A rifle bullet weighing a few grams, propelled at the relatively high velocity imparted in a modern firearm, will release more energy upon impact than a slow-moving motor-truck weighing several tons. An understanding of this relationship will assist greatly in understanding prosperity and depression.

Two friends of mine were talking about the current depression. Said the sales counselor, "Why should we have a depression? Look at the money in the banks—savings accounts increasing—lots of gold. Look at the supply of commodities. Look at prices lower than they've been in 20 years. What's the answer?"

Then spoke the engineer: "If I should take you down to the railroad yard and point to a stationary locomotive and say, 'Look, there's an engine that yesterday pulled the Detroiter from here to New York in fourteen hours. It weighs just as much as it did yesterday. Why isn't it going any place?' what would you say? It seems to me that your statements about wealth represent simply a mass figure like the weight of that locomotive. Wealth *in motion* is a measure of prosperity just as mass times velocity squared is a measure of work done by that locomotive. Giving the weight of a locomotive doesn't give any knowledge of its ability to go places, and your telling me only about the mass of the Nation's wealth means nothing as a measure of prosperity. The mass of wealth has lost velocity, and if it continues to lose velocity you can have many times as much *static wealth* and it won't mean a thing as far as prosperity is concerned."

Another interesting and basic physical relationship that helps us to understand many human problems is that a substance that recedes before impact will outlast many times a material which resists it. Rubber tires will run for many weeks and for thousands of miles without appreciable wear, but, if you put a pair of hard-steel antiskid chains on your tires, the relatively hard steel will be worn out in a few hundred miles. I have seen soft-rubber sand-blast nozzles outlive nozzles of chilled iron.

This physical principle with which we are all so familiar forms the basis, not only of the philosophy of Christ, but it is the genesis of many other Eastern philosophies. "Whosoever shall smite thee on thy right cheek, turn him the other also"; "A soft answer turneth away wrath." Witness the present triumph of Mahatma Gandhi of India, who has opposed the aggression of British rule by a simple policy of non-resistance.

I might go on almost indefinitely, pointing out the interesting relationships between certain eternal verities in the realm of physical law and the behavior of human beings and the dynamics of money matters.

### Industry Must Help Solve Social Problems

The industrial and social fabric of our civilization has come to be so much one and the same thing that it is doubtful if industry can escape the natural evolutionary tendencies toward more complete participation in the solution of pressing social problems. A few years ago

(*Concluded on p.* 184)

# Motorcoach Frame and Body Coordination

Transportation Meeting Paper

By George H. Scragg[1]

MOTORCOACH bodies are inherently rigid because of their box form and can tolerate very little flexing or weaving because of their glazing and the necessity for quiet. Attempts have been made at flexible body construction and flexible chassis mounting. Doubtless possibilities in both directions exist; but so far all such efforts have resulted in localized stresses in the complicated framing of the body, which requires much heavier construction if permanence and quiet are to be realized.

Frame rigidity is by all odds the easiest solution of the body-builder's problem, although truly rigid chassis frames have proved anything but simple for the chassis designer. Because motorcoach bodies should be low, the kick-up in the rear of the frame early made its appearance, and more recently the front drop also has been used. These introduced cranks in the side rails which greatly aggravated the tendency of the frame to weave. Space limitation and the desirability of a low floor, even under light load, have required limited spring deflection, which in turn has increased the twisting moments.

Outriggers have long been used to support the floor through the outer sills, instead of directly from the chassis frame, because the entire superstructure of the body is supported from the body sills at the outer edges of the floor and passenger weight is carried largely outside of the frame. The outriggers, being cantilevers, impose more torsional stress on the side members and magnify the effects of frame weaving. This has led to the necessity of either trussing across from side to side at the outriggers or attaching them rigidly to main cross-members; and it has also required increase in the stiffness of body sills, so these are usually of steel.

Bodies and frames unfortunately share in common the point at which maximum weaving occurs. This is at the front door, where the door opening interrupts the sheer side and the large opening for the dash and windshield preclude the bulkhead that would be desirable. Torsion in the chassis tends to localize at the same point because of the rigidity of the front part of the frame, which is both required and imparted by the engine mounting, and the lack of cross-members between this point and the middle of the driveshaft. Body designers have met this condition by greatly increasing the rigidity of the cowl and the windshield arch. Chassis builders have cooperated by placing the greatest depth of side members at this point, by the use of extra-stiff cross-members in the vicinity of the clutch, and by enlarging engine hoods to take larger and stiffer cowls.

Satisfactory as the progress has been along these lines, much of the success of the effort depends upon scientific determination of the best locations for anchor bolts. This has already been learned in the passenger-car field, where the problem is much simpler.

Complete rigidity of chassis or body structure is, of course, impossible to attain. A satisfactory compromise is reached when deflections are not too great to be allowed for by flexible cushioning strips. The location of the anchor bolts then becomes a matter of extreme importance. Study of frame stresses will reveal nodes or neutral axes about which flexure takes place. These are the ideal points, so far as the chassis is concerned, for the location of anchor bolts. The same applies to bodies. Slight modifications of design in both body and chassis structure permit these nodal points to be shifted to more favorable locations; perfect coordination requires that they be placed so as to register. Where too great a span intervenes between successive nodal points, yielding supports must be used if racking of the body or rumbling on the frame is to be avoided.

The wheelbase was once the principal chassis dimension, and wheelbases seem to have been chosen in even feet or for their euphony. The result was often that the wheel housing came at such a point that coordination with the seats was impossible. The wheelbase is now dependent upon the standard seat spacing for the type of body for which the chassis is designed.

Many early designs were laid out with insufficient consideration for the clearances actually required, so that the kick-up was often excessive both in length and height and seriously interfered with the construction of the floor between the wheels. Body considerations and boundary dimensions are now the determining factors. The inside height of the kick-up is just sufficient to clear the axle when the differential housing is at the maximum height allowed by the ramp, and the length of the kick-up is reduced to the minimum consistent with strength at the bends.

Present trends are distinctly toward absorbing the kick-up, as such, in the new ramped form of frame. Heretofore the frame was made approximately flat from the dash to the beginning of the kick-up, resuming the same plane back of the kick-up. Construction of the body floor, however, was developing along the line of a ramp, being inclined at a slight angle from near the front door to the highest point over the rear axle and then horizontal to the rear end. The effect was a decided discrepancy in form between the frame and the floor. Accordingly, in the newer frames the upper surfaces follow the contour of the floor save where a rudimentary kick-up clears the rear axle. This makes for both greater frame rigidity, by reducing the torsional moment at the kick-up, and simpler and more secure body mounting.

Basic characteristics of motorcoach design today are being conceived as a unit, with the requirements of the body as the principal design consideration. To what extent this line of progress will modify conventional motorcoach outlines and details of construction is indicated by the work already accomplished in chassis of the hoodless mass-transportation type. Even on the more conventional types, greater compactness is being secured by straddle-type dashes, semi-forward controls and engines designed for longitudinal compactness.

The time is fast approaching when the necessary but multitudinous and bulky engine accessories must be relocated or even driven by auxiliary engines, as on ships, if the powerplant is not to be entirely smothered and made completely inaccessible by them. All of the newer motorcoach engines show evidences of having had their basic design modified to bring the vital points requiring access out from behind the stockade of accessories. Forward controls may yet force the development of one-sided engines, as in England today. But whatever course development may take, the body must and will be the starting point.

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# New Riding-Comfort Research Instruments and Wabblemeter Applications

By F. A. Moss, M. D.[1]

**Annual Meeting Progress Report**

IF you were starting to design a new building, you would not guess at the dimensions; they would be carefully measured, utilizing the most accurate devices available. You can roughly estimate the length of lines merely by looking at them, but you will often be surprised to find how erroneous are your subjective judgments in that field. Try estimating the comparative length of the two lines *AB* and *XY* in Fig. 1. Is *AB* longer than *XY*, the same length or shorter? This problem was recently given to a group of about 500 engineers, the lines being drawn on a blackboard, and only about 8 estimated that *AB* was the longer. About 450 estimated that *AB* and *XY* were the same length, while about 40 estimated that *AB* was shorter than *XY*. By actual measurement, *AB* was 36 in. and *XY* 30 in. The cause of the large error was the effect of the angles at

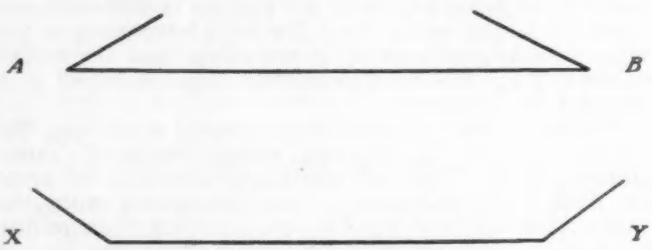



FIG. 1—TEST FOR SUBJECTIVE VISUAL JUDGMENT

Is the Line *AB*, Including the Inclined Lines, Longer than the Line *XY*, the Same Length, or Shorter? Only 8 Out of about 500 Engineers Answered This Question Correctly

the ends of the horizontal lines. Such experiments show that we see things not as they are but as they are surrounded.

So it is with other subjective judgments. The more subjective they are the more inaccurate they are. Most of our feelings are registered in terms of subjective judgments. For example, we may estimate the temperature of a room by our subjective feeling. If you wish to test your ability to do this, write down on a slip of paper your estimate of the temperature and then look at the thermometer. This experiment also was tried with the group of 500 engineers, and, although the temperature of the room was only 59 deg. by the thermometer, only two engineers estimated it so low, and the estimates ran all the way up to 78 deg., the average being around 68 deg.

Before the invention of the clinical thermometer, the old-time physician had to depend for his judgment whether a patient had a fever very largely upon whether the patient told him he felt hot. No physician today would be so foolish as to try to estimate a patient's temperature in that way, for they all know how inaccurate are the subjective estimates of patients.

A third experiment will again demonstrate how unreliable are our subjective estimates based on the internal measuring devices of our own bodies. The aforementioned group of automotive engineers was asked to estimate an interval of 11 sec. from the starting of a stop-watch at the word "go" to its stopping at the word "stop." Ninety-five of the estimates were too high, and the range of estimates was from 9 to 35 sec., the average being about 17 sec.

### Accurate Objective Instruments Needed

These experiments show clearly that when we depend upon subjective estimates of the riding qualities of an automobile we are dealing with very unreliable data. If we desire to secure any worthwhile data, we must substitute objective measuring devices for subjective guesses. The accuracy of objective measuring devices is the best index of the scientific development in any specific field. Our subjective measuring devices are not only very crude and inaccurate, but the number of these devices which we possess is extremely limited. While we have eyes with which to estimate the length of lines, ears with which we estimate the volume of sound, and pain receptors with which we estimate the severity of harmful stimuli, many important things happen in the human body for which we have absolutely no subjective measuring device and of which we are often totally unaware. For example, a man may be developing diabetes; his blood sugar may be two or three times what it should normally be, yet he has no subtle internal subjective sense that will tell him even crudely how high or low his blood sugar is. Fortunately, we can take some of his blood and accurately measure the blood sugar in any biochemical laboratory.

The object of the foregoing discussion is to emphasize the need of developing instruments with which we can secure accurate quantitative measurements. With such instruments we can collect data and largely discard the unreliable subjective guesses so generally used in measuring the intangible qualities of riding comfort.

### A Visiometer and a Reaction-Time Instrument Developed

The Riding-Comfort Subcommittee of the Society's Research Committee has succeeded in developing three instruments that seem to have considerable promise in this field. After much preliminary study and investigation, we have a fairly reliable instrument for measuring bodily steadiness. Many members of the Society have seen our wabblemeter and know how it works. It is now being made by the Pioneer Instrument Co., which can supply it to anyone upon relatively short notice.

More recently we have developed a new instrument known as the visiometer. This instrument and a third one, to be mentioned, have been developed upon the principle that fatigue has many manifestations. The wabblemeter measures the effect of fatigue only upon general bodily steadiness. Measurement of its effect upon other reactions would give a more complete picture. Therefore the visiometer was developed for study of the effect of fatigue upon the visual apparatus. It

[1] Head of department of psychology, George Washington University, City of Washington.

is based upon the principle that a tired person will not be able to adjust in a short time interval, by a simple movement, a variable light to a standard intensity. The apparatus is simple, yet very promising. It consists of a suitable portable housing at the end of which two openings are made and is similar to the old familiar stereoscope. The other end of the apparatus has two lamps, one of 3.8 volts, which is lighted directly by dry cells. The other lamp, of 2.3 volts, obtains its current from the same source but through a variable resistance.

If the resistance is set to zero, the 2.3-volt lamp burns with much more intensity than the 3.8-volt lamp. By properly adjusting the rheostat, a normal non-fatigued person can adjust the intensity in about 10 sec. so that the two lamps burn with equal brightness. The rheostat is graduated in arbitrary units, and the divergence from 0 (equal intensity) gives an index of eye fatigue. Only indirect light is used, a color screen being employed to eliminate glare. We are now using this instrument in experimentation and hope to have collected many data with it by the time of the next Annual Meeting.

The third instrument that we have developed, namely, a reaction-time instrument, also seems to have merit. A seemingly logical assumption is that, as one's nervous fatigue develops, especially if the fatigue is excessive, his reaction time will increase. Therefore we have constructed an instrument designed to measure the length of time a driver takes to move his foot from the accelerator to the brake of a car. Tests will be made with this instrument after varying periods of automobile driving, and data will be collected, just as was done in the case of the wabblemeter. At the next Annual Meeting of the Society we shall be prepared to report the results of a large number of road tests taken under varying conditions with all three instruments.

### Wabblemeter Tests After Airplane Flights

With the cooperation of the Ludington Lines, the wabblemeter was applied last summer and autumn in measuring fatigue produced after airplane riding, the tests being made in each instance before and after flights of more than 200 miles between Newark, N. J., and the City of Washington. A large number of tests were made on pilots of the airline and a considerable number also on passengers. The pilots tested showed an average increase of 42 per cent in wabblemeter record after the flight, the least increase shown by any pilot tested being 16 per cent, and the greatest, 73 per cent. The passengers tested showed an average increase of 77 per cent, the least increase being 24 per cent, and the greatest, 161 per cent.

Facts worthy of attention in this series of tests are: Pilots, as a group, showed a considerably more steady normal of before-flight records on the wabblemeter than did passengers. The passengers showed a much higher percentage of increase in wabble after the flight than did pilots. The increase in wabblemeter readings for the passengers is somewhat greater than is the increase for an equal distance covered by more usual means of travel. This does not hold true, however, for the increases found in the case of the pilots. This might suggest a factor of importance in producing unsteadiness after airplane riding, other than fatigue from vibration and lack of smoothness in operation of the plane, which is absent in the pilot accustomed to flying; that is, a factor akin to "air sickness."

Practical applications of the wabblemeter that might be suggested for experimentation in airplane testing include:

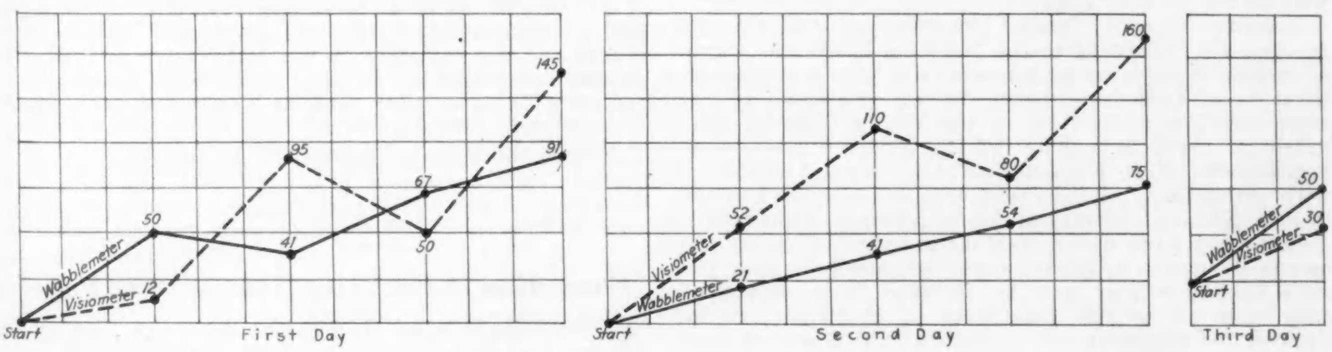
(1) Testing of comfort of airplane travel as compared with other modes of travel

(2) Testing of condition of pilots before flight; for example, if a pilot, whose normal record is about a 20 reading of the wabblemeter, shows a reading of 35, his fitness for flight on that particular day should be carefully checked

(3) Testing of recruits for aviation training, after a study has been made of the correlation between steadiness as measured by the wabblemeter and good flying

### Further Tests on Automobile Trips

Additional tests have been made on fatigue produced by long-distance travel by automobile, for further testing of the usefulness of the wabblemeter in measuring



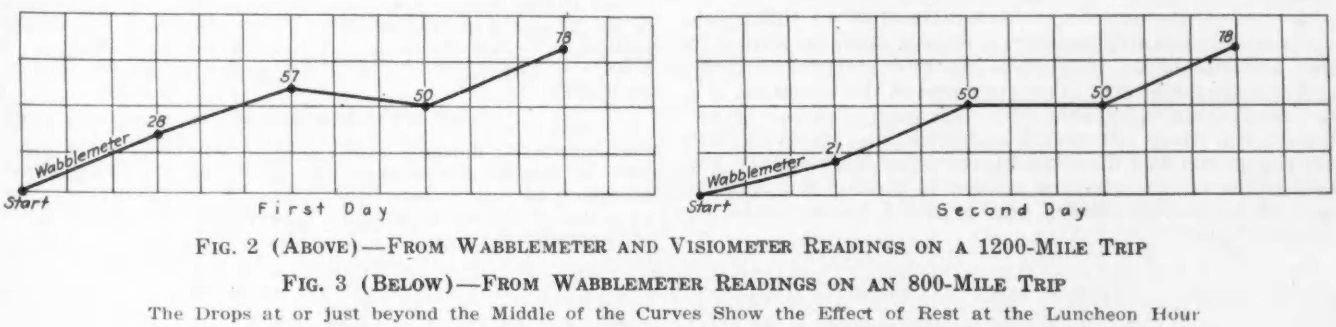




FIG. 2 (ABOVE)—FROM WABBLEMETER AND VISIOMETER READINGS ON A 1200-MILE TRIP

FIG. 3 (BELOW)—FROM WABBLEMETER READINGS ON AN 800-MILE TRIP

The Drops at or just beyond the Middle of the Curves Show the Effect of Rest at the Luncheon Hour

RECORDS OF FATIGUE TESTS ON LONG AUTOMOBILE TRIPS

the effects of automobile riding upon bodily condition, and, in the case of one trip, also with the object of gathering data for the development of the visiometer for measuring effects of fatigue and discomfort. In the last instance, one purpose was to check such measurements against wabblemeter index. Figs. 2 and 3 represent the results of these tests.

The wabblemeter records substantiate our previously reported findings for long-distance trips, in which we have found a considerable percentage of increase of fatigue with travel, the increase bearing a positive relationship to distance traveled but varying with varying conditions of road and other more extraneous driving conditions. The tests with the visiometer show a positive relationship of the records to length of driving time and to fatigue as indicated by the wabblemeter index. Further experimentation with and perfection of such an instrument may give us an additional measuring device of considerable value in the measurement of general physiological fatigue.

### Other Applications of Wabblemeter

The wabblemeter has been used in tests with a large number of other vehicles, including sailboat, interurban and city-type motorcoaches, street-car, subway train, steam train and ferryboat; but the number of cases tested is not sufficiently large for the data to be reliable or convincing.

Some experiments recently made, in which the wabblemeter was used, are of interest. In an investigation reported in one of the papers presented at the recent meeting of the Association for the Advancement of Science, the wabblemeter was used in measuring changes in steadiness after varying periods of nocturnal sleep. This supplements very well our own investigations of the diurnal changes in steadiness[2], which were reported at the 1931 Semi-Annual Meeting of the Society. The recent investigation showed that people are at a level of considerable unsteadiness at bedtime, which grows somewhat worse until they have obtained about 2 hr. of sleep, and that from then on steadiness improves with increasing periods of sleep.

The wabblemeter has been used recently also in a study of the effects of severe fatigue produced in the laboratory by strenuous exercise for a short time. Decreases in steadiness were shown by the instrument, but the decreases were not so great as we might expect from the strenuousness of the exercise. It may be that general bodily steadiness is affected more by a given amount of exercise or work spread over a long time than if concentrated in a very short time.

Such investigations as these laboratory studies give valuable information for standardizing our readings and interpreting the variables that must be considered in evaluating fatigue tests.

[2] See S.A.E. JOURNAL, September, 1931, p. 243.

## Constants and Variables in Production and Production Men

(*Concluded from p.* 180)

we not only questioned State compensation insurance, we looked upon it as a pernicious and socialistic measure. How many of us would choose to return to the old order of things—to personal-injury suits in the hands of blackmailing, shyster lawyers? And how much safer our shops are today than they were in the days before we had the present system!

Recently Gerard Swope, president of the General Electric Co., proposed to the National Electrical Manufacturers Association a comprehensive plan for the stabilization of industry. Owen Young, chairman of the same company and author of the Young Plan for Reparations, spoke in support of the Swope Plan. Many hard-headed New England manufacturers accepted it with enthusiasm. It has been accepted and is endorsed by the National Electrical Manufacturers Association.

You may have many mental reservations about the means proposed by Mr. Swope for accomplishing the ends in view. You may be justified in a degree of skepticism as to the feasibility of coordinating the worker, the employer, the public and the State without creating machinery so cumbersome as to defeat its purpose, but competent observers believe that we shall presently and inevitably have in industry such measures as life and disability insurance, unemployment insurance and old-age pensions. If you can accept this premise, is it not reasonable to assume that such measures will be administered more effectively and with less waste if they are organized and directed by industry than will be the case if the same measures are set in motion and administered by public officers and financed from special or general taxes?

As you survey your future problems and plan your prosperity programs, you will find it interesting and perhaps profitable to study the Swope Plan and the comments that are being made upon it by many able thinkers.

As we emerge from this period of subnormal activity, it will be well for all of us to look beyond the immediate and pressing demands of our jobs; to sort out the constants and the variables in the technical, economic and human aspects of our future work; to realize that, as industry becomes more complex, our viewpoints must become more comprehensive.

Now is the time to prepare for prosperity!

## Correction in Fuel-Line Temperature Paper

A TYPOGRAPHICAL error in the Bridgeman and White paper on Fuel-Line Temperatures in Cars of 1932, published in the S.A.E. JOURNAL for December, 1931, has been noted by a sharp-eyed member of the Society. Under the equation of the Appendix on p. 452 for the relation of change of vapor pressure of a gasoline with change of temperature,

$$\log (\pi/14.7) = A(1-\theta_n/\theta) \qquad (2)$$

the statement "where $\pi$ is the true, or gas-free, vapor pressure in pounds per square inch at 0 deg. fahr. absolute" should read "at $\theta$ deg. fahr. absolute", $\theta$ being the temperature in absolute degrees fahrenheit corresponding to the pressure $\pi$.

# Standardization Progress

## Insulated-Cable Report

### *Subdivision's Proposed Revision of Specification Published for Industry's Comment*

SEVERAL years ago the Electrical Equipment Division of the Society's Standards Committee conducted a series of tests on the effect of corona on automobile ignition cable, with the purpose of formulating a standard corona test. Although this has not proved feasible, the work led to a revision of the old S.A.E. Standard in 1926. Since that time practice has changed considerably in the manufacture and use of cable, and late in 1930 a new Subdivision was organized consisting of W. S. Haggott, Packard Electric Co., chairman; William Barth, General Motors Corp.; H. B. Burley, Boston Insulated Wire & Cable Co.; F. B. Kingsbury, Whitney Blake Co.; E. A. Robertson, General Cable Corp.; H. H. Wermine, Belden Mfg. Co., and J. E. White, Chrysler Corp. After considerable work, the Subdivision has submitted the following proposed revision of the present S.A.E. Standard as printed in the 1931 S.A.E. HANDBOOK, pp. 212 to 217.

In general, the changes made in the present standard are to omit the reference to Hevea rubber; to include pyroxylin lacquered cable and omit enameled cable; to provide for marker threads for identification, and to revise slightly the armor specifications. For secondary ignition cable, the stranding has been made more flexible and the rubber insulation increased. The number of types of this cable has been reduced from four to three by eliminating "rubber-covered and varnished cambric-taped and braided cable." The specification for primary ignition cable has been rewritten and the minimum wall thickness included. The previous seven types of insulation for this cable have been reduced to that given below, while the specification for lighting and starting-motor cable has been reduced to the three types shown under Item V. In Table 4, specifications have been included for nominal wire sizes Nos. 2, 6 and 18. The table also indicates whether the strands are laid concentric, bunched or rope. The maximum outside diameter of strands, the braiding specification and maximum outside diameters for the three types of insulation have been added, and some of the dimensions in the table have been changed to meet current practice.

This proposed new specification is published in this issue of the S.A.E. JOURNAL to give the entire automobile industry an opportunity to review it and submit any constructive comments to the Electrical Equipment Division before it submits the revised specification to the Society for adoption. Such comments should be addressed to the Standards Department of the Society not later than April 15, to reach the Division in time for consideration.

#### INSULATED CABLE

##### I. GENERAL SPECIFICATIONS

*Conductors.*—Conductors shall be bunched or stranded as specified in each section and shall be of annealed copper wire in accordance with specification No. B3-15 of the American Society for Testing Materials. All tinned wires must withstand the tinning test as specified in Section II, Tests.

*Rubber Insulation.* — Rubber insulation shall be homogeneous in character, properly vulcanized and placed concentrically about the conductors. Rubber insulation shall adhere closely to, but shall strip readily from, the conductors, leaving them reasonably clean and in suitable condition for soldering.

Rubber insulation used on cables covered by these specifications shall contain not less than 20 per cent, by weight, of good grade rubber that has not been previously used.

*Varnished Cambric Tape.* — Varnished cambric tape shall be made from a good grade closely-woven cotton fabric with multiple coats of insulating varnish. The instantaneous-puncture voltage shall be not less than 750 volts per mil thickness tested in accordance with American Institute of Electrical Engineers Standard, Section 30—Wires and Cables.

Varnished cambric tape shall be not less than 0.005 in. thick for wires No. 10 A.w.g. and smaller. For wires No. 8 A.w.g. and larger varnished cambric tape shall be not less than 0.007 in. In no case shall it be more than 0.013 in. thick.

*Braids.*—Braids shall consist of closely-woven cotton yarn and shall not be less than 1/64 in. thick and shall be covered with multiple coats of pyroxylin lacquer or impregnated with multiple coats of properly dried heat, oil and water-resisting insulating varnish or when specified, impregnated with black weather-proof wax compound that thoroughly saturates the braid and that has an even and smooth finish. Adjacent layers of cable when wound on the reels shall not stick to one another at any temperature under 105 deg. fahr. (40 deg. cent.).

*Identification.*—All cables shall have a marker thread or threads laid under or over the insulation to identify the manufacturer.

*Armor.*—Armor shall be solid D-shaped of either galvanized or sherardized dead-soft steel, soft brass, aluminum or copper and applied in a close helix. Successive turns shall not overlap. Armor dimensions shall be as given in Table 1.

TABLE 1—ARMOR THICKNESS AND WIDTH DIMENSIONS

| Armor | Thickness, In. | | | Width, In. | | |
|---|---|---|---|---|---|---|
| | Minimum | Nominal | Maximum | Minimum | Nominal | Maximum |
| Small.......... | 0.014 | 0.017 | 0.020 | 0.045 | 0.050 | 0.055 |
| Large.......... | 0.017 | 0.020 | 0.023 | 0.095 | 0.100 | 0.105 |

The small size of armor shall be used on sizes Nos. 18 to 10 A.w.g. inclusive, and the large size on No. 8.

##### II. TESTS

*Tinning Tests.*—For this test, samples of the bare wire before being stranded or insulated shall be properly selected to secure an average grade of tinning. The wires shall be thoroughly cleansed by means of ether, benzine, gasoline, naphtha, alcohol or carbon tetrachloride, whichever may be found necessary to clean the wires thoroughly. Care shall be taken to avoid abrasing or scratching the samples of wire to be tested.

The wires shall then be rinsed in clear water and wiped dry with a soft cotton

TABLE 2—HIGH-TENSION OR SECONDARY IGNITION CABLE

| Nominal Size | | Number of Wires in Strand | Nominal Size of Wires in Strand, A.w.g. | Maximum Outside Diameter, In. | Minimum Outside Diameter, In. | Minimum Thickness of Rubber Wall, In. | | |
|---|---|---|---|---|---|---|---|---|
| Mm. | In. | | | | | Plain Rubber Covered | Single Braid | Double Braid |
| 7 | 0.2756 | 19 | 29(0.0113) | 0.285 | 0.265 | 0.104 | 0.089 | 0.074 |
| 9 | 0.354 | 19 | 29(0.0113) | 0.364 | 0.344 | 0.143 | 0.128 | 0.113 |

The 7-mm. size is recommended for all high-tension cable.

TABLE 3—PLAIN RUBBER-COVERED LOW-TENSION OR PRIMARY IGNITION CABLE

| Nominal Size | Number of Wires in Strand | Nominal Size of Wires in Strand A.w.g. | Max. Outside Diam. In. | Min. Outside Diam. In. | Min. Wall Thickness, In. |
|---|---|---|---|---|---|
| 5 mm. (0.197 in.) | 19 | 29 (0.0113) | 0.207 | 0.187 | 0.065 |

The above cable is recommended as a grounding cable for short-circuiting magnetos, etc.

cloth. The wires shall then be immersed for 1 min. in a solution of hydrochloric acid having a specific gravity of 1.088 at 70 deg. fahr. (21 deg. cent.), and then rinsed in clear water and wiped dry as above specified. The wires shall then be immersed for 30 sec. in a solution of sodium-polysulphide having a specific gravity of 1.142 at 70 deg. fahr. (21 deg. cent), which contains an excess of sulphur. The sodium-polysulphide solution shall be maintained at a sufficient strength to blacken thoroughly a piece of clean, untinned copper wire in 5 sec.

The complete cycle of operations shall then be repeated, commencing with the immersion in hydrochloric acid and ending with the immersion in the sodium-polysulphide solution.

Tests of tinning shall be made on not less than 10 sets of samples of reasonable length. All tests shall be conducted with the solution at a temperature of 70 deg. fahr.

After completing the above two cycles of dips, the samples of wire shall be examined to ascertain, through blackening caused by the sodium-polysulphide solution, whether the copper is exposed. The samples shall be considered to have failed if by such blackening the copper shall be shown to be exposed.

*Physical Tests.*—A test specimen of rubber insulation, which has not previously been handled, not less than 6 in. long shall have marks placed upon it 2 in. apart. The sample shall then be stretched at the rate of 12 in. per min. until these marks are 6 in. apart, and then immediately released. Thirty seconds after being released the distance between the marks shall not exceed 2½ in. The test specimen shall then be stretched until the marks are 7 in. apart before it is ruptured.

The tensile strength of rubber insulation

(*Concluded on p. 36*)

TABLE 4—LIGHTING AND STARTING-MOTOR CABLES

| Nominal Size, A.w.g. | Number of Wires in Strand and Type of Strand | Nominal Size of Wires in Strand | | Maximum Outside Diameter of Strand | Circular Mills in Strand | | Thickness of Rubber Wall, Minimum | Braid | | | Maximum Outside Diameter, In. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A.w.g. | In. | In. | Nominal | Actual | In. | Cotton Size | Number of Ends | Picks Per In. Minimum | Plain Rubber | Rubber and Braid | Varnished Tape and Braid |
| 18 | 16 Concentric<br>41 or Bunched | 30<br>34 | 0.0100<br>0.0063 | 0.052<br>0.054 | 1,624 | 1,600<br>1,627 | 0.022 | 30/2 | 2 | 24 | 0.105<br>0.110 | 0.135<br>0.140 | 0.120<br>0.130 |
| 16 | 19 Concentric<br>26 or Bunched | 29<br>30 | 0.0113<br>0.0100 | 0.057<br>0.062 | 2,580 | 2,409<br>2,600 | 0.022 | 30/2 | 2 | 24 | 0.110<br>0.115 | 0.140<br>0.145 | 0.125<br>0.135 |
| 14 | 19 Concentric<br>41 or Bunched | 27<br>30 | 0.0142<br>0.0100 | 0.071<br>0.074 | 4,110 | 3,831<br>4,100 | 0.027 | 30/2 | 3 | 20 | 0.135<br>0.140 | 0.165<br>0.170 | 0.140<br>0.145 |
| 12 | 19 Concentric<br>65 or Bunched | 25<br>30 | 0.0179<br>0.0100 | 0.090<br>0.094 | 6,530 | 6,088<br>6,500 | 0.031 | 30/2 | 3 | 22 | 0.160<br>0.165 | 0.190<br>0.195 | 0.160<br>0.165 |
| 10 | 19 Concentric<br>49 or Bunched | 23<br>27 | 0.0226<br>0.0142 | 0.113<br>0.130 | 10,400 | 9,679<br>9,880 | 0.031 | 30/2 | 3 | 24 | 0.185<br>0.200 | 0.215<br>0.230 | 0.185<br>0.200 |
| 8 | 19 Concentric<br>49 Rope | 21<br>25 | 0.0285<br>0.0179 | 0.142<br>0.165 | 16,500 | 15,390<br>15,700 | 0.037 | 30/2 | 3 | 26 | 0.225<br>0.250 | 0.255<br>0.280 | 0.230<br>0.250 |
| 6 | 37 Concentric<br>133 Rope | 21<br>27 | 0.0285<br>0.0142 | 0.200<br>0.213 | 26,250 | 29,970<br>26,800 | 0.047 | 30/2 | 3 | 26 | 0.305<br>0.320 | 0.335<br>0.350 | 0.285<br>0.300 |
| 4 | 61 Concentric<br>133 Rope | 22<br>25 | 0.02535<br>0.0179 | 0.228<br>0.269 | 41,741 | 39,162<br>42,560 | 0.047 | 30/2 | 3 | 20 | 0.330<br>0.375 | 0.370<br>0.415 | 0.325<br>0.365 |
| 2 | 127 Concentric<br>259 Rope | 23<br>26 | 0.0226<br>0.0159 | 0.294<br>0.335 | 66,371 | 64,694<br>65,786 | 0.0625 | 20/2 | 4 | 9 | 0.430<br>0.470 | 0.475<br>0.515 | 0.395<br>0.435 |
| 1 | 127 Concentric<br>259 Rope | 22<br>25 | 0.02535<br>0.0179 | 0.330<br>0.376 | 83,692 | 81,613<br>82,984 | 0.0625 | 20/2 | 4 | 9 | 0.465<br>0.510 | 0.510<br>0.555 | 0.430<br>0.477 |
| 0 | 127 Concentric<br>259 Rope | 21<br>24 | 0.0285<br>0.0201 | 0.370<br>0.422 | 105,535 | 102,866<br>104,636 | 0.0625 | 20/2 | 4 | 10 | 0.505<br>0.555 | 0.550<br>0.600 | 0.470<br>0.525 |
| 00 | 127 Concentric<br>259 Rope | 20<br>23 | 0.03196<br>0.0226 | 0.415<br>0.474 | 133,077 | 129,723<br>131,935 | 0.0625 | 20/2 | 4 | 11 | 0.550<br>0.610 | 0.595<br>0.655 | 0.515<br>0.575 |

In above table a standard flexible and extra-flexible stranding is shown for each gage size, the flexible strand being the first one given in each case.

Tinned conductors shall be used on all extra-flexible sizes and on flexible sizes Nos. 18 to 10 inclusive when rubber covered. On flexible sizes Nos. 8 to 00 inclusive, where rubber insulation is used, untinned strand may be used with kraft-paper separator 0.0025 in. thickness and applied with one-quarter lap. On all flexible sizes when insulated with varnished cambric untinned copper may be used if desired.

When bunched stranding is used, the length of core lay for sizes Nos. 18 to 12 inclusive shall be a maximum of 2 in. For No. 10 the lay shall be a maximum of 3 in.

Maximum outside diameters given for rubber-covered cables include a tolerance on rubber diameter of — 0.000 + 0.010 in. Braiding specifications on sizes Nos. 18 to 4 inclusive are based on 16-carrier braiders and on sizes Nos. 2 to 00 on 24-carrier braiders.

Glazed thread shall be used on sizes Nos. 18 to 6 inclusive and soft-finished thread on sizes Nos. 4 to 00.

On varnished-cambric cables the tape must be wrapped sufficiently tight to prevent the conductor being pulled from a 3-in. length of cable under a load of 10 lb.

# Transportation Engineering

## Repair and Junking Standards

### *Factory-Approved Clearances and Tolerances Needed on Fits for Vehicle Elements*

STANDARDS for maintenance practice were outlined by Joseph Geschelin[1] in the paper he presented at the 1932 Annual Meeting. He stated in part that recent figures compiled by his company place 1931 United States truck registration at 3,300,000 vehicles, representing an investment of $3,500,000,000. A statistical average over the last five years indicates that truck operators are making an average yearly investment of about $360,000,000 in new equipment and replacements. But early estimates indicate that in 1931 the maintenance of passenger-cars and trucks involved the expenditure of $1,550,000,000 for parts and $2,330,000,000 for labor in utilizing them. He asked whether this tremendous capital investment can be administered more economically, and answered "yes," with the help of repair standards he proposed. If, in a typical case a breakdown occurs and the vehicle must be put back on the road quickly with the minimum of expense, how can the service man or field inspector determine what the minimum cost should be? he queried, when no one has set up instructions to show what may be safely used, what may be salvaged, and how much should be junked immediately.

Mr. Geschelin stated the consensus to be that a crying need for a sensible workable code of instructions for maintenance work exists, and if one is devised it must come from the manufacturer. But it must be based on information thoroughly threshed out between factory engineers, their service organization and the users. An abstract of some of the major points of his paper follows:

#### Repair-Service Standards

Suppose we call this code "Repair Service Standards" for want of a better name. What would it look like? Briefly, it might consist of a system of factory-approved clearances and tolerances on fits for the vital reciprocating, oscillating and revolving elements. These data could be expressed in the following form: Class 1, the *desirable limit*, which will give the original factory dimension and clearances. Very little of this is known today, much to the detriment of economical service. Class 2, the *intermediate limit*, is to be defined later. Class 3, the *junking limit*, would specify the condition of maximum wear between mating parts beyond which it is not safe to operate. Practical service men also will want additional information along the following lines:

(1) The permissible endplay in shafts, such as camshafts and crankshafts
(2) Since cylinders are frequently rebored, the maximum volume of metal that can be removed before the block must be scrapped
(3) The permissible backlash in the various gear trains
(4) Determination of the maximum clearance between piston and cylinder before serious oil pumping occurs
(5) Establishment of limits for out-of-round, taper and oversize for cylindrical fits
(6) The depth of case of carburized and heat-treated parts such as gears, piston-pins and shackle bolts. The usable depth of case usually should be the limit for maximum wear
(7) Minimum brake-drum thickness. This would limit the maximum amount of material removed in truing operations

With this bare statement of an objective, conceded by many to be a tangible approach to efficient and economical operation, let us admit our keen appreciation of the complexities involved. To establish a workable code is no simple task; it will take time, energy and money. Since we must take into account the variations in service conditions and all the complications that go with that, we should start with the assumption that these standards will not be universal in application; that they will vary with the make of unit or vehicle; may vary from model to model in the same line; and may vary in the same fleet.

#### Proposed Set-Up Stated

Standards, as at present conceived, may be divided into two broad classes: (*a*) Specific Standards, unique for each make of vehicle, being the code proposed in this paper; and (*b*) so-called Universal Standards, which constitute an accumulated experience of the service field. This paper proposes the following set-up:

Class-1 clearances to be given in the form of an upper and lower limit, due to the tolerances permitted in production. This limiting band is intimately tied up with the design of the part. It should be used as the par value for rebuilding and for replacement parts. The establishment of the Class-1 clearances is more basic than most of us realize. It involves, first, an intimate statistical knowledge of service life or wear life. In turn, nominal life is intimately related to the character of the tolerances and the way in which these can be maintained in production.

A simple way of explaining the meaning of "wear life" and its relation to the original factory tolerances is shown in Fig. 1. If we define wear life as a measure of the thickness of a layer of material that may be removed in service, then the wear life of a given element will be the layer shown. The next two circles represent respectively the condition of minimum clearance,

[1] M.S.A.E.—Engineering editor, *Automotive Industries*, Philadelphia.

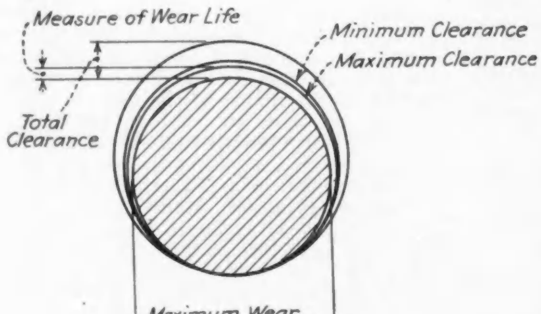



FIG. 1—ILLUSTRATION OF THE MEANING OF "WEAR LIFE" AND ITS RELATION TO FACTORY TOLERANCES

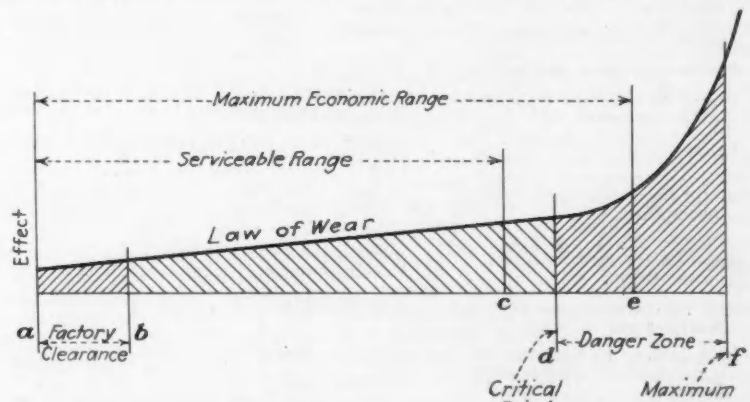



FIG. 2—DIAGRAM ILLUSTRATING AN ANALYSIS OF THE RELATIONSHIP OF WEAR EFFECTS AND CLEARANCE

due to the possible combination of factory tolerances on both the shaft and the hole. The inner shaded portion is the diameter of the shaft at maximum wear. It is startling to observe that the useful wearing layer of material may be only a relatively small proportion of the total clearance between the outer circle and the inner circle. In some cases the useful life, as measured by the thickness of the material that may be removed in service, is almost all gone before the vehicle is placed in operation.

Recent discussion in connection with the preparation of this paper indicates that the Class-2 clearance may require a redefinition and a new significance. Thus far, our conception of it has been that of a serviceable limit. This point of view was discussed by the writer in a recent article[2]. But mature thought indicates that something more is needed. For the assumption is that, if a unit is torn down and found to be within the boundary of Class 2, it should be usable, perhaps even without adjustment if the element is adjustable. Is this practicable without reservation?

The analysis in Fig. 2 is offered merely as a suggestion to a rational approach. It will be assumed for the purpose of discussion that a great many elements in a vehicle, during the course of normal events, follow some law of wear as represented by the curved line. The graph shows the relation between effects and the clearance in the element at any time in its life. The band between points *a* and *b* indicates a range of clearances produced in the run of production. Assume that normal wear takes place gradually, uniformly and practically along a straight line, as shown from *a* to *c*, the slope of the line representing some service effects which are expected as a part wears. But at *d*, a critical point is reached which can be isolated in many cases. Beyond this, the behavior of the element becomes abnormal, and enters a danger zone—the band between *d* and *f*. At *f*, a conception of one of the factors entering into the definition of Class 3 is indicated. This limit should be taken as the point of maximum wear and, regardless of service conditions, the element should be renewed, replaced, adjusted or salvaged.

[2] See *Automotive Industries*, Sept. 19, 1931, p. 419.

It is now proposed that the clearance specified in Class 2 should represent the condition at the critical point *d*. Where are we if this is accepted? Obviously, if the inspector or the repairman finds an element at the critical point, he knows that it is at the danger zone. Depending upon his judgment and the experience of the particular operation, he may then permit the part to remain undisturbed until, say, the next regular inspection, when wear has progressed to some point *e*, which we may call the "maximum economic range."

Again, based on service experience and judgment, the operator will have available a "serviceable range," extending between *a* and *c*. In practice this will mean that, when a unit is torn down, those parts that have not worn beyond some limit of serviceable range, on the safe side of the critical point, will be regarded as serviceable and can safely be retained in their present condition.

The discussion of Fig. 2 practically defines the clearance in Class 3. However, in addition to mechanical clearance, other things must be considered. The condition of the wearing surfaces is chief of these.

### Universal Clearances Considered

Universal clearances are developed from the lore of the service field and generally represent total experience over a long period. Paul Dumas compiled and published a complete code of universal clearances for passenger-car service in a supplement to *Motor Age*, Nov. 6, 1924. J. A. Purvis collected data on current practice which was published in *The Automobile Trade Journal*, April, 1931. The most valuable feature of Purvis' work is that of indicating the way in which the part is measured and the correct tools to use. Col. Edgar F. Stayer, commanding officer at the Holabird Quartermaster Depot, permitted me to use the repair standards recently adopted there. Careful check of these data shows a noteworthy correspondence between these standards and the material compiled by Paul Dumas. The main thing to consider in connection with universal standards is the matter of non-conformity to conventional practice (See Table 1).

Assuming that standards are set up and are available to the service field, how shall they be applied in a practical way? Will this require significant changes in maintenance procedure and in the structure of service organizations now in existence? To some extent, yes, but only in a constructive sense, since the object of standardization is to simplify matters and reduce costs.

Out of a mass of suggestions culled from service men appear some outstanding factors that may specify an ideal maintenance set-up using factory-established standards. Its objective is to spot the weak element quickly and economically. Here is a suggested set-up:

(1) Set-up periodic inspection based on:
   (*a*) Service conditions, atmospheric conditions and terrain
   (*b*) Mileage, as in a case of motorcoaches; kilowatt output, as in a case of gasoline-electric vehicles; engine revolutions; ton-miles; gallon-miles and the like. The criterion is to be established by each operator
(2) Institute trouble diagnosis based on:
   (*a*) Establishment of good methods
   (*b*) Use of latest available instruments
(3) General instrumentation:
   (*a*) On the vehicle, for automatically recording essential data; speedometer, revolution-counter, recording devices, governor and the like
   (*b*) For diagnosis, see 2*b* above and discussion
   (*c*) For parts inspection: dial gages, inside micrometers, cylinder-bore micrometers, ball-bearing tester, scleroscope and magnetic crack-detector

Some satisfactory mechanical means must be found for checking ball bearings. The amount of money involved in the price of bearings, and even more so in the overhaul cost of the unit, is altogether too large to leave to the judgment of any individual. A most ingenious device, striking in its simplicity, is the ball-bearing tester built by Gisholt Machine Co., Madison, Wis., for testing the bearings used in the Gisholt precision dynamic-balancing machine. The object is to test bearings dynamically instead of statically. All dimensions, including the run-out in both directions, can readily be checked by dial indicator gages.

An ideal example of an instruction manual is one published June 15, 1931,

(*Concluded on p. 36*)

TABLE 1—EXAMPLES OF NON-CONFORMITY TO CONVENTIONAL REPAIR STANDARDS SUGGESTED BY PAUL DUMAS

| Element | Conventional Clearance | Specific Exceptions |
|---|---|---|
| Spark-plug-point gap | 0.022-0.030 in. | 1932 Nash 9-80 0.015 in. Jordan A 0.018 in. warm Marmon 75 0.025-0.028 in. |
| Diameter clearance clutch sleeve | 0.0015-0.002 in. | Certain passenger car 0.003-0.004 in. due to aluminum-alloy material used |
| Lining to drum clearance | 0.006-0.015 in. | Steeldraulic brake 0.025-0.055 in. |
| Pinion ring-gear backlash hypoid | 0.008-0.012 in. | Packard 1932 hypoid 0.004-0.005 in. |
| Piston to cylinder-wall diameter clearance | 0.0005-0.00075 in. per in. of diameter | William piston-drive fit in bore |
| Front-wheel toe-in | 1/16-3/16 in. | Cord front-drive car with zero toe-in |
| Weight variation piston-rod assembly | ½ oz. | Cadillac 8-314 8 lb. 25/32 oz. ± ⅛ oz., due to type of crankshaft used |
| Eccentricity medium-gage brake-drum | 0.003-0.010 in. maximum | Steeldraulic, serviceable with 0.016 in. eccentricity |
| End clearance connecting-rod bearing or crankpin | 0.004-0.008 in. | Wills-Sainte Claire 8 0.002-0.003 in. |
| Piston to cylinder-wall clearance before audible slap is heard | 0.008 in. approx. | In some cars the same bore will slap with 0.005-in. clearance |
| Tappet clearance | | Buick 121-129 0.008 in., warm Nash 8-80 0.012 in., warm |

# News of the Sections

(*Continued from p. 27*)

bership experience, motion pictures of the manufacture of automobile storage-batteries were shown.

### Noise Causes and Remedies

Speaking on the acoustical treatment of mufflers, air-cleaners and air-silencers for carbureters, Mr. Jack said that, while the public may not be able to distinguish between intake roar and that from differential gears, it wants quiet operation, and silence has become essential to satisfactory car performance. He mentioned the parts that cause the more important noises in the modern car and said that tire noise has become more evident with better silencing of other parts. Future car bodies of streamline design will be quieter, which makes necessary the giving of more attention to silencing the mechanical parts.

While we may use 100 hp. to make a car pleasant to drive, only about 1/1,000,000 hp. of sound energy can make the car almost intolerable to some drivers, according to Mr. Jack.

Valve trouble may be caused by too much back pressure in mufflers, but such troubles are not likely to become serious until the back pressure reaches 7 or 8 lb. per sq. in., as it may easily do in a car that has been used for some time. A gain of 1 hp. at top speed may be expected for each 1 in. of mercury reduction in back pressure, and we may expect an increase of about 1 m.p.h. in top speed for each 2 or 3 hp. increase at top speed of a typical car.

Noise in the carbureter air intake is caused by an action that is somewhat similar to that which causes water hammer, said the speaker, and can be overcome by providing absorption chambers for cushioning and damping out the sound waves. Vibration of the muffler tail pipe also may cause noise.

In the discussion, G. H. Hedrick, chief engineer of the Gem Mfg. Co., said that his experience had been that reduction in back pressure resulted in a very noticeable increase in acceleration; and "Joe" Harvey, automotive engineer of the Pittsburgh Railways Co., expressed interest in the possible improvement of 4 per cent in miles per gallon of fuel through reduction of back pressure. Other discussers included F. W. Heisley, Charles R. Noll, Clyde Mathis and Murray Fahnestock.

## Shock-Absorber Session at Dayton

DAYTON Section's monthly meeting on Feb. 22 was entirely devoted to consideration of shock-absorbers and included a visit after the technical sessions to the plant of the Delco Products Corp. to observe the mass production of shock-absorbers. The meeting was held in the Engineers Club, where 45 members and guests sat down at dinner and 125 heard the three speakers of the evening.

A résumé of early shock-absorber patents and attempts to secure better riding qualities in the days of the "horseless carriage" was given by B. D. Kunkle, president and general manager of the Delco Products Corp. "Ride control," which is a feature on a number of 1932-model automobiles, was thought about even in the pioneer days of the industry, according to Mr. Kunkle, who then went on to describe the various types of shock-absorber and tell why ride control is being used.

Various methods of testing shock-absorbers and the riding qualities of motor-cars were next described by E. F. Rossman, shock-absorber engineer of the Delco Corporation, who presented curves of the frame action with and without absorbers and at temperatures ranging from 0 to 115 deg. fahr. He then told how the steam-engine indicator is used in testing shock-absorbers and showed the varying forces at the end of the arm when using the ride-control feature.

Finally, C. H. Kindl, chief engineer of the Corporation, explained some of the problems that confront the engineer in endeavoring to secure a perfect ride free from noise.

At the plant of the Corporation in Dayton the members of the Section observed the various manufacturing operations and the testing of shock-absorbers, where each instrument is required to give an indicator curve showing a pressure or action that is predetermined for a particular installation.

## Junking Standards Considered

REDUCTION of fleet maintenance costs through the formulation and adoption of a code of standards for junking worn parts of vehicles was the theme of an address given by Joseph Geschelin, of the Chilton Class Journal Co., at the March 9 meeting of the Philadelphia Section, which was held in the rooms of the Philadelphia Automobile Trades Association. The meeting was attended by 55 members and guests and was preceded by a dinner and entertainment enjoyed by 40.

Mr. Geschelin's paper was based on the one he gave at the Annual Meeting of the Society in January, in which he outlined a suggested code of junking standards. A summary of that paper and of the discussion on it is printed in this issue of the S.A.E. JOURNAL in the department of Transportation Engineering.

The particular angle emphasized at the Philadelphia Section meeting was the value to fleet operators of having such a code established. The speaker pointed out that, if many large operators are convinced that a code of the sort is necessary, the truck manufacturers will find that fact sufficient incentive to start a movement for the formulation and adoption of a definite code of tolerances and limits of working parts which will serve as a guide to vehicle users how long to continue worn parts in service and when to replace them.

Discussion of the subject was participated in by B. B. Bachman, of the Autocar Co.; James H. Cottrell, technical editor of the *Commercial Car Journal;* Mr. Wilkinson and Mr. Stoeckel.

## President Scaife Addresses Northwest's Meetings

THE high mark of the year for the Northwest Section was reached at the meeting held on March 10 at Seattle, in the main banquet room of the New Washington Hotel, when 200 members and guests greeted President A. J. Scaife; Secretary and General Manager John A. C. Warner; and Prof. F. G. Baender, of the Oregon State College engineering school. President Scaife was emphatically optimistic regarding the future of the transportation field and saw a place for each type of carrier. Mr. Warner expressed optimism for the Society and announced that the Get-Your-Man campaign has brought in 100 applications since Feb. 1. Professor Baender discussed the Trend of Current Research in Automotive Powerplants in his characteristically clear manner.

C. H. Bolin, Section Chairman, presided most ably. Reece Lloyd reported progress in the membership drive. Sherman W. Bushnell outlined the programs for the final two meetings of the season. The April meeting is to be devoted to aeronautics, with C. W. Monteith, of the Boeing Airplane Co., as the principal speaker. The May meeting is to be the first one that the Section has ever devoted entirely to motorboats.

The Nominating Committee announced nominations of Section officers for the coming year.

H. W. Drake, Chairman of the Oregon Section, was present and proposed holding a joint meeting with the Northwest Section. President Scaife announced that he would award a banner to the winner of a membership drive to be staged between the Portland and the Seattle groups.

### Regulation Only to Correct Abuses

Following Mr. Warner's address on the progress of and the outlook for the Society, President Scaife quoted figures showing the magnitude of the automotive industry and its important place in American life. He opposed Federal regulation of trucks, stating that it would be practically impossible. Trucks, he declared, do not constitute a transportation system like that of the railroads, and the two cannot be coordinated. The same kind of regulation cannot be applied fairly to all means of transportation, he contended; a special kind must be applied to the truck. He declared that the general public conception that trucks and motorcoaches are given free use of highways, and are in this sense subsidized, is false.

Data on road thickness for heavy

traffic, the effect of speed on roadbeds and the fact that any increase in costs of highway construction made because of trucks and motorcoaches is fully paid for by them, were further points developed by Mr. Scaife. He intimated that motor transport should be regulated by the Federal Government only to correct abuses, if such develop. The best form of transportation—that desired by the public—will survive, he said.

### Phases of Acceleration Analyzed

Professor Baender narrowed his discussion to the acceleration built into present engines. He advised that those who engage in research work of this type be well grounded in mathematical concepts and sound engineering. To improve acceleration, more is required than building larger engines, for difficulties arise to offset merely making engines bigger. The rotating speeds of engines are now at their practical limit and further increases do not seem logical in the light of engineering principles, he stated. The trend is to increase the compression ratios; but, although this seems simple, it is a subject filled with interesting mathematics. The technical designer or research engineer must know more than his mechanics; he must know fuels that are available for his use, said the speaker. Hence the problem of higher compression ratios is mutual with the petroleum and the automotive industries.

### Meeting Held at Vancouver, B. C.

The Northwest Section held a meeting at Vancouver, B. C., on the evening of March 8, at which President Scaife and General Manager Warner were honor guests and gave interesting talks. Charles E. Boyle was local chairman. Lieutenant-Colonel Letson presented a paper on Diesel-Engine Designs. The following members from Seattle were present: C. H. Bolin, D. F. Gilmore, A. M. Jones, R. C. Pitzer and Sherman W. Bushnell.

## Cooling Systems Thoroughly Discussed at Milwaukee

UNDER the title, Engine Cooling, a scientific and mathematical treatment of the problem of cooling the powerplant of the automobile was presented at the March meeting of the Milwaukee Section by Louis Schwitzer, president of the Schwitzer-Cummins Co. Other speakers were A. J. Scaife, President of the Society, who spoke on Some Phases of Highway Transportation; and John A. C. Warner, General Manager of the Society, who talked on the work of the Society, with special reference to membership, and showed motion pictures of the 1931 Summer Meeting.

The meeting was held the evening of March 2 at the Milwaukee Athletic Club, where 85 members and guests attended the members' dinner, at which entertainment was provided, and 135 were present at the technical session. At a brief business session Chairman A. C. Wollensak, of the Nominating Committee, presented the names of the nominees for Section offices for the coming year. H. L. Horning, Past-President of the Society, and J. B. Armitage, Past-Chairman of the Section, who were scheduled to take part in the program, were absent because of illness.

Mr. Scaife gave data on current motor-truck and highway legislation, pointing out the many existing inconsistencies and lack of uniformity in limitation of size and weight and in taxes imposed. He said that the small volume of less-than-carload freight now transported by trucks should not appreciably affect the revenue of the railroads and does not justify their demands for increased taxation of motor-trucks.

### Requirements of Efficient Cooling

In Mr. Schwitzer's excellent paper, the author dealt with the theory and fundamentals of the cooling of internal-combustion engines, which he declared is not a difficult problem. He discussed in detail fans, circulating spaces in engine blocks, water-pumps and radiators and their interrelation. Summarizing, he said that the elements necessary for an efficient cooling system are (*a*) an efficient fan; (*b*) provision for air outlets; (*c*) an adequate fan drive; (*d*) a cooling-liquid circulation sufficient to maintain reasonably small temperature drops and give proper distribution, especially with regard to radiator and jacket design; and (*e*) a radiator core that will give the maximum temperature rise of the air, together with the maximum volume of air passing through it.

## Research Engine and Vibration Discussed by Hoosiers

ROY W. PATON, experimental engineer of the Perfect Circle Co., and Robert N. Janeway, of the engineering division of the Chrysler Corp., were the speakers who drew an attendance of 185 at the monthly meeting of the Indiana Section on March 10. The technical session followed the members' dinner at the Hotel Severin in Indianapolis, at which 50 members and guests were present.

Mr. Paton presented an interesting paper, prepared by himself and Lee Brannon, which described a high-speed engine built by his company for research work on piston-rings and some of the results obtained with it. This was generously illustrated with lantern slides. As a result of tests with conventional automobile engines on a dynamometer and their contact with the problems of the various engine builders, the engineers of the piston-ring company decided to concentrate the work in a piston-ring research laboratory in its own plant.

As built, the test engine has a single working cylinder and two balancing cylinders cast as a unit and fastened to the lower half of the crankcase. Counterbalancing pistons work in the balancing cylinders. The water-pump discharges to a distributing valve by which the water can be directed to the lower end of the cylinder block or through an oil-cooler, thus making possible the control of the oil temperature within the desired limit. Pressure lubrication of conventional system is employed. The crankshaft is carried on four main bearings, providing unusual rigidity and also long bearing life.

### Can Test Wide Range of Cylinders

The working cylinder is readily removable from the upper half of the crankcase, and cylinders ranging from 2⅞ to 4-in. bore can be tested, including L-head and valve-in-head types. Any of the cylinders can be operated with a wide variation of compression distance and ratio. The camshaft is located to permit the use of a variety of valve sizes and locations and is provided with an adjustable tappet screw, so that correct combustion-chamber proportions can be maintained.

Specimen curves were shown of corrected horsepower and friction horsepower at speeds up to 3300 r.p.m., of blow-by and oil consumption at engine speeds equivalent to 50 to 70 m.p.h., and full-power blow-by with two pistons of widely different types, one having a very rigid skirt and the other a slightly flexible skirt.

### Vibration-Study Devices Shown

Mr. Janeway exhibited an interesting diversity of devices for demonstrating the various types of vibration which were studied by the Chrysler Corp. research division in evolving the "floating power" engine mounting of the Plymouth and Chrysler cars. He presented a paper entitled, Application of Vibration Fundamentals to Engine Mounting.

## Dayton Section and A.S.S.T. Meeting

IN a joint meeting of the Dayton Section of the S.A.E. with the Dayton Chapter of the American Society for Steel Treating on March 8 at the Engineers Club, 100 members and guests of the two Societies heard three interesting speakers. M. M. Goldberg, consulting engineer of Dayton and inventor connected with the National Cash Register Co., gave an interesting informal talk at the dinner on his recent visit to Russia and the Soviet industrial plants.

At the technical session, Walter T. Fishleigh spoke on the subject, Engineering Leadership; and Ray T. Bayless, technical secretary of the A.S.S.T. in Cleveland, presented a paper entitled, Metallurgical Testing without a Laboratory, which was written by E. E. Thum, editor of *Metal Progress*, who was unable to attend the meeting.

## Chicago Holds Ladies' Night

APPROXIMATELY 100 women and 163 men attended the Ladies' Night dinner and entertainment of the Chicago Section held the night of March 16 at the Hotel Sherman. A very entertaining talk on Audible Light was given by John Bellamy Taylor, consulting engineer of the General Electric Co., after which a ladies' prize contest was held. Favors for men and women were provided and the rest of the evening until midnight was devoted to dancing.

# Personal Notes of the Members

### *Carver Writes of Soviet Industry*

After spending nearly two years in Russia as a special representative on the staff of the president of the General Motors Export Co., of New York City, Walter L. Carver returned recently, after which he severed his connection with the company. During his stay in Russia he visited many automotive plants in different cities and investigated various phases of industrial activity under the Soviet five-year plan and was enabled to judge the progress made in contrast with conditions observed during nearly a year spent in Russia prior to the present régime as an executive of an American tractor company.

Conditions in the four great Soviet plants as he observed them were described in an interesting and informative way by Mr. Carver in *Automotive Industries* for March 5, p. 375; and those on the motor-car and motor-truck plants were described in a second instalment in the March 12 issue of the same periodical.

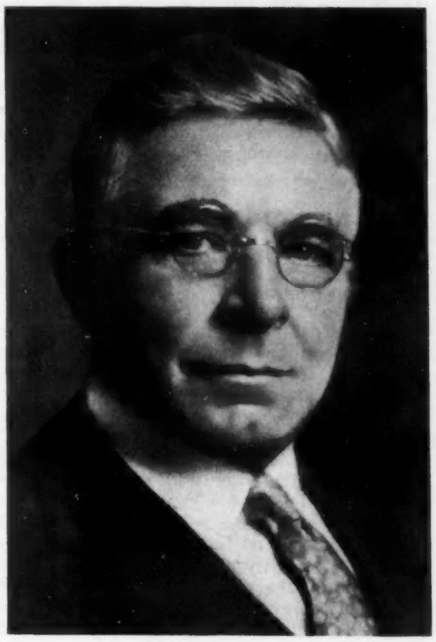
Mr. Carver has been engaged in engineering, manufacturing and market and economic analysis work, chiefly in the automotive industry, for the last 20 years. After three years in the engineering department of the Peerless Motor Car Co., of Cleveland, he was engaged from 1913 to 1917 in development and design, research and field work, shop organization and production for the Wallis Tractor Co., of Cleveland, Ohio, and Racine, Wis., and spent a year abroad for that company, chiefly in Russia. Subsequently, he engaged in similar work with the tractor branch of the Moline Plow Co., of Moline, Ill., and the Midwest Engine Co., of Indianapolis. After a period of consulting and development work in the automotive and agricultural fields, he joined the editorial department of the Chilton Class Journal Co., of Philadelphia, and served as field editor from 1923 to 1927. During the succeeding year and a half he served as a member of the sales committee of the Kelvinator Corp., of Detroit, in charge of market analysis and statistical work. In 1928, he joined the General Motors Corp. as manager of the sales department, and in the following year was transferred to the staff of the president of the General Motors Export Co., in New York City.

Mr. Carver was elected a Member of the Society in 1921.

### *Irvin Elected President of United States Steel Corp.*

Rising step by step in the steel industry during the last 35 years, from the position of shipping clerk with the P. H. Laufmann Co., of Apollo, Pa., William A. Irvin, an Associate Member of the Society since 1923, has been chosen by the Board of Directors of the United States Steel Corp. to succeed to the presidency of the Corporation upon the retirement of James A. Farrell on April 19.

This high honor, announced early in March by Myron C. Taylor, chairman of the finance committee of the Corporation, comes as a recognition of the valuable services rendered by Mr. Irvin for many years as operating vice-president of the American Sheet & Tin Plate Co., a subsidiary of the United States Steel Corp. On Sept. 1, 1931, he was appointed vice-president, in charge of operations, of the parent corporation, with his headquarters in New York City, and at that time many in the industry assumed that this was a move preparatory to delegating to him more important responsibilities. As president, he will be operating head of the Corporation, a field with which he is thoroughly familiar through his long steel-mill experience.



WILLIAM A. IRVIN

Mr. Irvin, who was born at Indiana, Pa., in 1873, started his business career at 15 years of age when he became a telegrapher with the Pennsylvania Railroad, and later was made freight and ticket agent. He first entered the steel industry in 1895, as shipping clerk with the P. H. Laufmann Co., manufacturer of steel sheets and tin plate, and worked successively in various departments, finally being advanced to the position of superintendent of the mill. When the Laufmann company was absorbed by the American Sheet Steel Co. in 1900, Mr. Irvin was transferred to New York City, and when the latter company was merged with the American Tin Plate Co. four years later, he was appointed assistant to the operating vice-president. After holding that position for 20 years, he was made vice-president in charge of operations.

Besides being an Associate Member of the S.A.E., Mr. Irvin holds memberships in the American Society for Testing Materials, the Engineers Society of Western Pennsylvania, the Pittsburgh Chamber of Commerce and several athletic clubs.

### *LaSchum Made Automotive Department Manager*

Following the recent retirement of E. E. Bush from active service with the Railway Express Agency in New York City and the abolition of the department of maintenance and purchases, which was under his jurisdiction, E. E. LaSchum was appointed manager of the automotive department. He also has charge of the purchasing of automotive equipment, accessories and supplies for the department. Prior to this appointment, Mr. LaSchum was general superintendent of motor-vehicle equipment for the agency.

Since becoming a Member of the Society in 1915, Mr. LaSchum has been active in the work of the organization, having been a member of the Publication Committee in 1927 and 1928 and of the Operation and Maintenance Committee in 1927.

### *Dresser with Investors Syndicate*

Since the beginning of this year, Sidney R. Dresser has been city manager for Greater New York with the Investors Syndicate Title & Guaranty Co., of New York City, and is now "engineering incomes." He had been executive engineer of the Kent Garage Investing Co., also of New York City, for three years prior to making this new connection, and before that was chief cable engineer of the Whitney Blake Co. Mr. Dresser has been a very active member of the Metropolitan Section, of which he was Vice-Chairman in 1928 and Chairman in 1929.

**Eric G. Almquist,** having left the Packard Motor Car Co., of Detroit, for which he was a designer in the aircraft division, recently accepted a position with the General Motors Corp. Research Laboratories in Detroit as a designer in the powerplant section.

**Gilbert A. Burn** is now serving the Sun Oil Co. in Detroit. His former connection was with the International Motor Co., of Allentown, Pa., as engineer in charge of the experimental division of the engineering department.

**F. J. Druar** was recently appointed assistant sales manager of the Bower Roller Bearing Co., of Detroit. He previously held the position of sales engineer with the Timken Roller Bearing Co., of Canton, Ohio.

**William D. Drysdale** is now chief engineer of Electric Devices, of Buffalo, which builds household ice machines. His former position was that of superintendent in charge of manufacturing

*(Concluded on p. 50)*

# Standardization Progress

(*Concluded from p.* 30)

shall not be less than 600 lb. per sq. in. The tensile strength shall be calculated upon the original cross-section of the test specimen before stretching.

Physical tests shall be made at a temperature of not less than 50 deg. fahr. (10 deg. cent.), nor more than 90 deg. fahr. (32 deg. cent.).

For the purpose of these tests, care must be used in cutting to obtain samples of uniform cross-section and no manufacturer shall be responsible for results obtained from samples imperfectly cut.

The above physical tests shall not apply to wires or cables having a wall thickness of less than 0.045 in. For wires and cables having a wall thickness of less than 0.045 in. the initial and ultimate stretch shall be 5 and 6 in. respectively, and the tensile strength not less than 500 lb. per sq. in.

*Oil Test for Braided Cables.*—This test shall apply to all braided cables that have either a lacquered or a varnished finish.

Samples of cables shall be immersed in a mixture of equal parts of engine oil and gasoline for a period of 24 hr. without allowing the ends of the sample to become submerged. After this immersion the lacquer or varnish should not show signs of softening or absorption, and when the braids have been peeled off, it should be shown that no oil has penetrated to the rubber insulation. In making this test a shallow vessel shall be used to hold the mixture of engine oil and gasoline so that the sample of wire may be immersed without a sharp bend or the necessity of sealing the ends of the wire.

III. Specification for High-Tension or Secondary Ignition Cables

The conductors shall be of tinned copper wires. High-tension or secondary ignition cables shall be one of the following constructions as specified by purchaser:

(1) Plain rubber covered
(2) Rubber covered with single braid
(3) Rubber covered with double braid.

A weather-proof waxed braid shall not be used on this type of cable.

High-tension or secondary ignition cable sizes shall be as given in Table 2, and when braided shall be lacquered or varnished as specified in the paragraph "Braids" in the General Specifications to withstand the oil-test specifications for braided cables as given in Section II.

IV. Specification for Plain Rubber-Covered Low-Tension or Primary Ignition Cable

The conductors shall be of tinned copper wires and shall be insulated with one layer of rubber. Low tension or primary ignition cable shall be as given in Table 3.

V. Specification for Lighting and Starting-Motor Cables

Conductors shall be bunched or stranded as shown in Table 4, and insulated in one of the following ways as specified by purchaser:

(1) Plain rubber-covered
(2) Rubber-covered and single-braided
(3) Two layers of varnished cambric tape and single braid.

The braid shall be lacquered, varnished or weather-proof as specified in paragraph under General Specifications.

Construction of these cables shall be as shown in Table 4.

VI. Specifications for Armored Lighting Cables

Conductors shall be bunched or stranded as shown in Table 4, and insulated in one of the following ways as specified by purchaser:

(1) One cotton cover, one layer of varnished tape, one braid, armor
(2) Two layers of varnished tape, one braid, armor
(3) Rubber covered, one braid, armor.

Armored construction shall not be used on cables larger than No. 8 gage.

On armored cables either soft finish or glazed thread may be used as desired. Braiding specifications as shown in Table 4 shall apply to armored cables. Braids shall be covered with multiple coats of pyroxylin lacquer or impregnated with multiple coats of properly dried heat, oil and water-resisting insulating varnish.

Untinned copper may be used on Types 1 and 2. Tinned copper shall be used on Type 3. Rubber-wall thicknesses on Type 3 shall be as shown in Table 4.

# Transportation Engineering

(*Concluded from p.* 32)

by the Pratt & Whitney Aircraft Co. In addition to discussing maintenance methods, inspection assembly and reassembly and the use of tools, it also has a comprehensive section on clearances. Fig. 3, taken from this book, shows the method. Three classes of clearances are specified wherever possible. The plus (+) mark, which appears in red in the book, indicates scrapping when the dimension is exceeded. At other points where three dimensions are given, the dimension to the left, slightly larger in type, appears in red in the book. This is the dimension at which the part is scrapped.

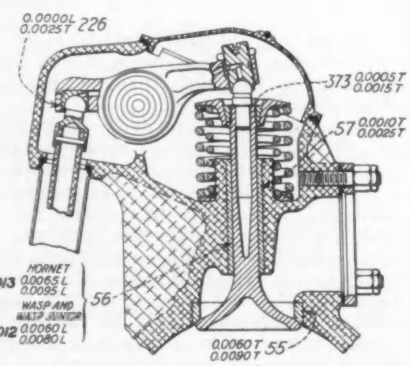



Fig. 3—An Illustration Showing Clearances, Taken from a Service Manual

Many fleet operators feel that economical operation of rolling stock hinges entirely upon the development of repair and junking standards. We have enough engineering ability and initiative in our industry to meet this challenge.

# Thurman H. Bane

MAJOR Thurman H. Bane, vice-president of the Aviation Corp. and executive vice-president of American Airways, Inc., of New York City, passed away on Feb. 22 at the Neurological Institute, Medical Center, in New York City.

Major Bane was elected to Member grade in the Society in March, 1919, and was also an associate member of the American Society of Mechanical Engineers.

Born at San Jose, Calif., in 1884, Major Bane was graduated from the United States Military Academy at West Point, N. Y., in 1907 and took the post-graduate course at the Ordnance School of Application, at Sandy Hook, N. J. From 1912 to 1914 he was student and proof officer in ordnance experimental engineering in the Ordnance Department of the Army; in 1914 and 1915 he was in charge of the forge plant, armory and chemical laboratory at the Rock Island Arsenal in Illinois and in the autumn of 1916 was attached to the Army Air Service at McCook Field, Dayton, Ohio. With the commissions of captain and colonel, he was chief of the engineering division of the Air Service for several years. He was then commissioned Major but retired from service in 1922 and was located at Monterey, Calif., until 1929. He then entered civilian activities as secretary and general manager of the West Indian Aerial Express, with headquarters in New York City, and the following year was elected vice-president of the Aviation Corp. He was active in laying out 9000 miles of night-lighted airways.

Major Bane became interested in aviation when he was on duty on the Mexican Border in 1914 as a lieutenant of cavalry, and as a student flier worked out a course in aerodynamics and design that was accepted as standard. He was made head of the Bureau of Military Aeronautics in 1917. Under his direction, while at McCook Field, the parachute that is now standard equipment was developed there. He also assisted subsequently in developing a scientific staff for supplementing the Weather Bureau forecasts of weather conditions for pilots and gave much attention to the installation of radio telephones in commercial airplanes.

# Arthur D. Ferguson

WITH deep regret the Ferguson Publishing Co., of New York City, announced the death of its president, Arthur D. Ferguson, in March.

Mr. Ferguson, who was elected an Associate Member of the Society in May, 1917, was a native of New York State, born at Utica in 1870. All his business life was devoted to the trade publishing field. He was publisher or associate publisher of technical and trade periodicals with the Gage Publishing Co. from 1895 to 1909; and then became president of the Ferguson Publishing Co., which published the *Automobile Buyers Reference*, later changed to *Motor Record.*

# Applicants for Membership

The applications for membership received between Feb. 15 and March 15, 1932, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANGUS, WILLIAM WORTHINGTON, sales manager, Collins & Aikman of Canada, Ltd., *Montreal, Que., Canada.*

BALL, GEORGE W., JR., mechanical engineer, Aeronautical Engine Laboratory, League Island Navy Yard, *Philadelphia.*

BERGER, ERNEST A., patent engineer, Mitchell Specialty Co., *Philadelphia.*

BISHOP, A. H., manager, Autocar Sales & Service Co., *Baltimore.*

BLOOM, CECIL A., engineer, American Propeller Co., *South Bend, Ind.*

BOWEN, B. H., district manager, Firestone Tire & Rubber Co., *New York City.*

BROOKE, W. LERCH, junior engineer, Vacuum Oil Co., *Paulsboro, N. J.*

BROWN, L. K., manager, L. K. Brown, Parliament and Carlton Streets, *Toronto, Ont., Canada.*

CALDWELL, J. RALPH, owner, Caldwell Trucking Co., *Detroit.*

CLARKSON, ALICK, chief engineer, Brooks Steam Motors, Inc., *Buffalo.*

CLEMENS, BENE F., inspection foreman, Bendix Aviation Corp., *South Bend, Ind.*

COLLINS, FRED A., coach representative, The White Co., *Cleveland.*

CUSHING, THOMAS W., assistant director of utilities, W. N. Albertson, *Milwaukee.*

DAVIDSON, LOUIS, shop superintendent, Edmonton Motors, Ltd., *Edmonton, Alta., Canada.*

DE COURSEY, E. M., special engineer, Bragg-Kliesrath Corp., *South Bend, Ind.*

DIEFENDORS, CLARENCE BYRON, assistant technical man, Vacuum Oil Co., *Kansas City, Mo.*

DIETER, ARTHUR R., 344 West 72nd Street, *New York City.*

DORMAN, BERNHARDT L., experimental engineer, Paragon Vaporizer Corp., *Chicago.*

DUNNING, HARRY, JR., mechanic, The Texas Co., *Beacon, N. Y.*

EARL, ELLIOTT, research assistant, Pennsylvania State College Engineering Experimental Station, *State College, Pa.*

FISHER, FRED J., manager of Baltimore branch, Sterrett Operating Service, Inc., *Baltimore.*

FLYNN, JOHN BURT, consulting engineer, Headlands Garage, *Wellington, N. Z.*

GALLAHER, RAYMOND W., manager, lubricating department, Pan American Petroleum Corp., *New Orleans.*

GIBBARD, GEORGE H., service-school instructor, General Motors Products of Canada, Ltd., *Toronto, Ont., Canada.*

GILLESPIE, DEAN M., district manager, The White Co., *Cleveland.*

GRAHAM, ERWIN W., student engineer, Chrysler Corp., *Detroit.*

GRANGER, HENRY R., salesman, Kolpack & Mitchell, *Baltimore.*

GRIZZLE, HOMER, zone parts and service manager, Chevrolet Motor Co. of Texas, *El Paso, Texas.*

GROVES, MARTIN V., assistant superintendent, United States Trucking Corp., *New York City.*

GUTHIER, RAY E., superintendent of transportation, Northern States Power Co., *Eau Claire, Wis.*

HATCH, ERVIN N., analysis engineer, Brooklyn Bus Corp., *Brooklyn, N. Y.*

HAVAS, DENES, sales manager, Motor Parts Co., *Philadelphia.*

HERRON, RALPH H., sales engineer, Carter Carburetor Corp., *St. Louis.*

HERSCHEL, WINSLOW H., associate physicist, Bureau of Standards, *City of Washington.*

HEWLETT, RALPH CLINTON, junior engineer, Eclipse Aviation Corp., *East Orange, N. J.*

HIGGINS, ELIOT W., engineer, Burgess Battery Co., *Madison, Wis.*

HILL, JOSEPH R., manager of field-service division, Standard Oil Development Co., *Elizabeth, N. J.*

HOAR, EVERETT, president, Hoar Transport Co., Ltd., *Toronto, Ont., Canada.*

HOLLISTER, DON C., engineering, Hudson Motor Car Co., *Detroit.*

HOUSER, JAMES FRANCIS, research fellow, Lehigh University, *Bethlehem, Pa.*

HURLEY, WILLIAM B., 321 Rivard Boulevard, *Grosse Pointe Village, Mich.*

KEELER, GEORGE, designing engineer, Aeromarine Plane & Motor Co., *Keyport, N. J.*

KRAUTHOFF, FIRST LIEUTENANT, SAMUEL VANCE, U. S. A., Brigade Motor School, *Schofield Barracks, T. H.*

LASSMANN, MAX, junior engineer, Chrysler Corp., *Detroit.*

LEWIS, HARRY R., vice-president, Conewango Refining Co., *Warren, Pa.*

LIBBEY, FREDERICK IRVING, chief engineer, Automatic Brake Co., *New York City.*

MAGRUDER, LIEUTENANT, CARTER B., U. S. A., post-graduate course in automotive engineering, Purdue University, *Lafayette, Ind.*

MALADY, BERNARD M., test foreman, Continental Aircraft Engine Co., *Detroit.*

MARTIN, A. D., field representative, Ethyl Gasoline Corp., *Seattle, Wash.*

MAURER, PAUL H., electrical engineer, Eclipse Machine Co., *Elmira, N. Y.*

MCALLISTER, JOHN T., research engineer, Standard Oil Development Co., *Linden, N. J.*

MCBRIDE, S. R., president, McBride's Garage, Ltd., *Toronto, Ont., Canada.*

MCCULLOUGH, CHARLES F., chief draftsman, Auburn Automobile Co., *Auburn, Ind.*

MIEHL, WILLIAM F., consulting engineer, 1200 Chambers Building, *Kansas City, Mo.*

MILLER, F. LAVERNE, research chemist, Standard Oil Development Co., *Elizabeth, N. J.*

MILLER, FREDERICK WILLIAM, manager of Toronto office, Collins & Aikman of Canada, Ltd., *Toronto, Ont., Canada.*

MILLER, OSCAR R., general sales manager, United States Graphite Co., *Saginaw, Mich.*

MORRISON, WALTER GEORGE, maintenance superintendent, City of Santa Monica, *Santa Monica, Calif.*

MOUAT, RUPERT CHARLES, student, General Motors Institute of Technology, *Flint, Mich.*

NAYLOR, FRANKLIN LLEWELLYN, JR., sales, Breeze Corp., Inc., *Newark, N. J.*

NELIS, IRVIN F., representative, Bendix-Westinghouse Automotive Air Brake Co., *Philadelphia.*

OLVER, ALBERT STEPHEN, automotive contact representative, Ethyl Gasoline Corp., *Toronto, Ont., Canada.*

PALM, JOHN V. O., chief engineer, Cleveland Graphite Bronze Co., *Cleveland.*

PAYETTE, JOSEPH A., assistant field engineer, United States Rubber Co., *Detroit.*

PEAT, LESLIE, managing editor, Chilton Class Journal Co., *Philadelphia.*

PETZOLD, EDWARD O., lubricating research engineer, Standard Oil Development Co., *Elizabeth, N. J.*

PORTER, BAKER EDDY, fleet manager, Olson Baking Co., *Los Angeles.*

RADTKE, W. H., West Coast representative, Hercules Motors Corp., *San Francisco.*

RENSING, CLIFFORD C., assistant chief engineer, Aluminum Industries, Inc., *Cincinnati.*

RISK, THOMAS HARRISON, junior engineer, Vacuum Oil Co., Inc., *Paulsboro, N. J.*

RUPPERT, WALTER J., owner, Motor-Ez Oil Co., *Baltimore.*

SCHIMPF, FRED J., supervising draftsman, Naval Aircraft Factory, League Island Navy Yard, *Philadelphia.*

SCHOMBURG, WILLIAM H., vice-president, Bingham Stamping & Tool Co., *Toledo.*

SCHWAM, MORTON, design draftsman, Naval Aircraft Factory, League Island Navy Yard, *Philadelphia.*

SCOVILLE, ROBERT WAGONER, junior engineer, Chrysler Corp., *Detroit.*

SETH, STEPHEN, president, Stephen Seth & Co., Inc., *Baltimore.*

SIEBERT, GEORGE E., superintendent of equipment, State of California Division of Highways, *Sacramento, Calif.*

SIMONS, JOHN P., sales engineer, Bendix-Stromberg Carburetor Co., *Chicago.*

SMITH, D. MYRLE, engineer, McQuay-Norris Mfg. Co., *St. Louis.*

SMITH, E. F., district superintendent of motor equipment, Gulf Refining Co., *Atlanta.*

SMITH, FRANCIS A., Standard Oil Co. of New York, *Buffalo.*

SORENSEN, ARTHUR S., president, N. C. Sorensen Motor Express Co., *Chicago.*

SWIGART, JOHN T., assistant general service manager, The White Co., *Chicago.*

TAYLOR, MATTHEW A., division manager, Ethyl Gasoline Corp., *New York City.*

TOEWS, GUSTAV P., senior engineer, Aeronautical Engine Laboratory, *Philadelphia.*

VEDOVELL, R. J., sales manager, Chicago Rawhide Mfg. Co., *Chicago.*

VON SODEN, ALFRED M., COUNT, director, Zahnradfabrik Friedrichshafen A/G., *Friedrichshafen, Germany.*

WARNECKE, CHARLES L., junior engineer, Vacuum Oil Co., *Paulsboro, N. J.*

WERTZ, DANIEL L., engineer, Eclipse Machine Co., *Elmira, N. Y.*

WESTACOTT, EDWIN HUGH, assistant head, transportation department, Caribbean Petroleum Co., *Maracaibo, Venezuela.*

# Notes and Reviews

## AIRCRAFT

**Ice Prevention on Aircraft by Means of Engine-Exhaust Heat and a Technical Study of Heat Transmission from a Clark-Y Airfoil.** By Theodore Theodorsen and William C. Clay. Report No. 403. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 24 pp., illustrated. Price 20 cents. [A-1]

The investigation herein reported was conducted to study the practicability of employing heat as a means of preventing the formation of ice on airplane wings. The report relates essentially to technical problems regarding the extraction of heat from the exhaust gases and its most effective distribution over the exposed surfaces. A separate study has been made to determine variation of the coefficient of heat transmission along the chord of a Clark-Y airfoil.

Relative merits of various methods of ice prevention by heat are analyzed, with the result that a vapor system was found to offer the most satisfactory solution, especially for airplanes that are not constructed entirely of metal. In all-metal designs, employing a direct exhaust-heating system may be entirely practicable.

**Dynamic Testing of Airplane Shock-Absorbing Struts.** By P. Langer and W. Thomé. Translated from *Zeitschrift des Vereines Deutscher Ingenieure*, Vol. 75, No. 45, Nov. 7, 1931. Technical Memorandum No. 656; 4 pp., 12 figs. [A-1]

**Resonance Vibrations of Aircraft Propellers.** By Fritz Liebers. Translated from *Luftfahrtforschung*, Vol. III, No. 3, May 16, 1930; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 657; 44 pp., 14 figs. [A-1]

**Problems Involved in the Choice and Use of Materials in Airplane Construction.** By Paul Brenner. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Vol. 22, No. 21, Nov. 14, 1931; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 658; 25 pp., 23 figs. [A-1]

**Airplane Flight in the Stratosphere.** By Ugo de Caria. Translated from *Aeronautica*, Vol. V, No. 12, December, 1931. Technical Memorandum No. 660; 13 pp., 2 figs. [A-1]

**Experiments with Planing Surfaces.** By W. Sottorf. Translated from *Werft-Reederei-Hafen*, Nov. 7, 1929. Technical Memorandum No. 661; 20 pp., 14 figs. [A-1]

The foregoing five Technical Memoranda were issued during January. February and March, 1932, by the National Advisory Committee for Aeronautics, City of Washington.

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**These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.**

**The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H. Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.**

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**On the Effect of the Walls of a Wind Tunnel upon the Lift Coefficient of a Model.** By Sasaki-Tatudiro. Report No. 77 of the Aeronautical Research Institute, Tokyo Imperial University, December, 1931; 26 pp. [A-1]

This is a continuation of Report No. 46 of the Tokyo Imperial University, noted in these columns of the April, 1929, issue, and deals with (*a*) the effect of an exit wall, (*b*) the case in which the model is replaced by a point vortex and (*c*) the effect of both the exit and the collector walls.

**A Contribution to the Analysis of Primary Stresses in the Hull of a Rigid Airship.** By L. Chitty and R. V. Southwell. Published in *The Journal of the Royal Aeronautical Society*, December, 1931, p. 1103. [A-1]

This paper describes an investigation conducted at the request of the Aeronautical Research Committee, which made a grant for the purpose, and was awarded the R. 38 Memorial Prize for 1931 jointly with W. G. Bird for his paper on The Influence of Atmospheric Humidity and Other Factors upon the Static Lift of Airships, which was reviewed in these columns in the March issue.

The present paper is highly technical and of considerable length.

**Hydraulic Brakes for Aircraft.** By R. Waring Brown. Published in *Aircraft Engineering*, December, 1931, p. 301. [A-1]

In a previous article, which was reviewed in these columns in the October, 1931, issue, the subject of wheel brakes for airplanes was surveyed and the various types of brake in use briefly described. The present article deals in detail with hydraulic brakes, which are receiving increasing attention for installation on aircraft.

The theoretical and practical qualities of brakes of the hydraulic type are discussed and descriptions of prominent examples are given.

**Müller-Breslaus Elastizitätstheorie des Starren Luftschiffs.** By Edgar Seydel. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Jan. 28, 1932, p. 46. [A-1]

The theories on rigid-aircraft construction formulated by E. H. Müller-Breslaus in the course of his connection with these developments, which began in the 1890's, were expounded by him in a hitherto unpublished address delivered in 1915. This address has just been made available for publication, and the present article serves as an introduction to it, reviewing the more important phases of the methods therein set forth for the design of the frame structure of rigid aircraft. Emphasis is laid upon the simplifications introduced and the possibility of applying the procedure to other problems. Some additional notes on the effect of a keel walkway on static calculations are included.

**Methods of Eliminating Ground Surveying for Control in Aerial Photographic Mapping.** By Earl Church. Published by Syracuse University, Syracuse, N. Y., 1932; 64 pp. [A-4]

This is the fifth of a series of papers on the theory of topographic surveying by measurements on aerial photographs.

In the previous papers on topographic mapping from measurements with the comparator, the stereocomparator and the photogoniometer, the method in each case was developed with the assumption that every photograph contained the images of three control points. That is, within the field of every photograph there were supposed to be three definite points whose space coordinates on the survey system of axes, or whose horizontal positions and elevations, had been determined by regular geodetic methods for terrestial surveying.

In each paper, together with this assumption, appeared the admission that this control entailed an excessive amount of ground work in connection with the aerial photography, and each time it was stated that a subsequent paper would discuss the elimination of at least part of this ground work.

In this paper four methods of eliminating ground control either entirely or partly are discussed. These are: (*a*) elimination of all ground-control work after the first pair of photographs in a flight series having 75 per cent longitudinal overlap; (*b*) control by elevations only; (*c*) control by horizontal positions only; and (*d*) elimination of all ground-control work after the first

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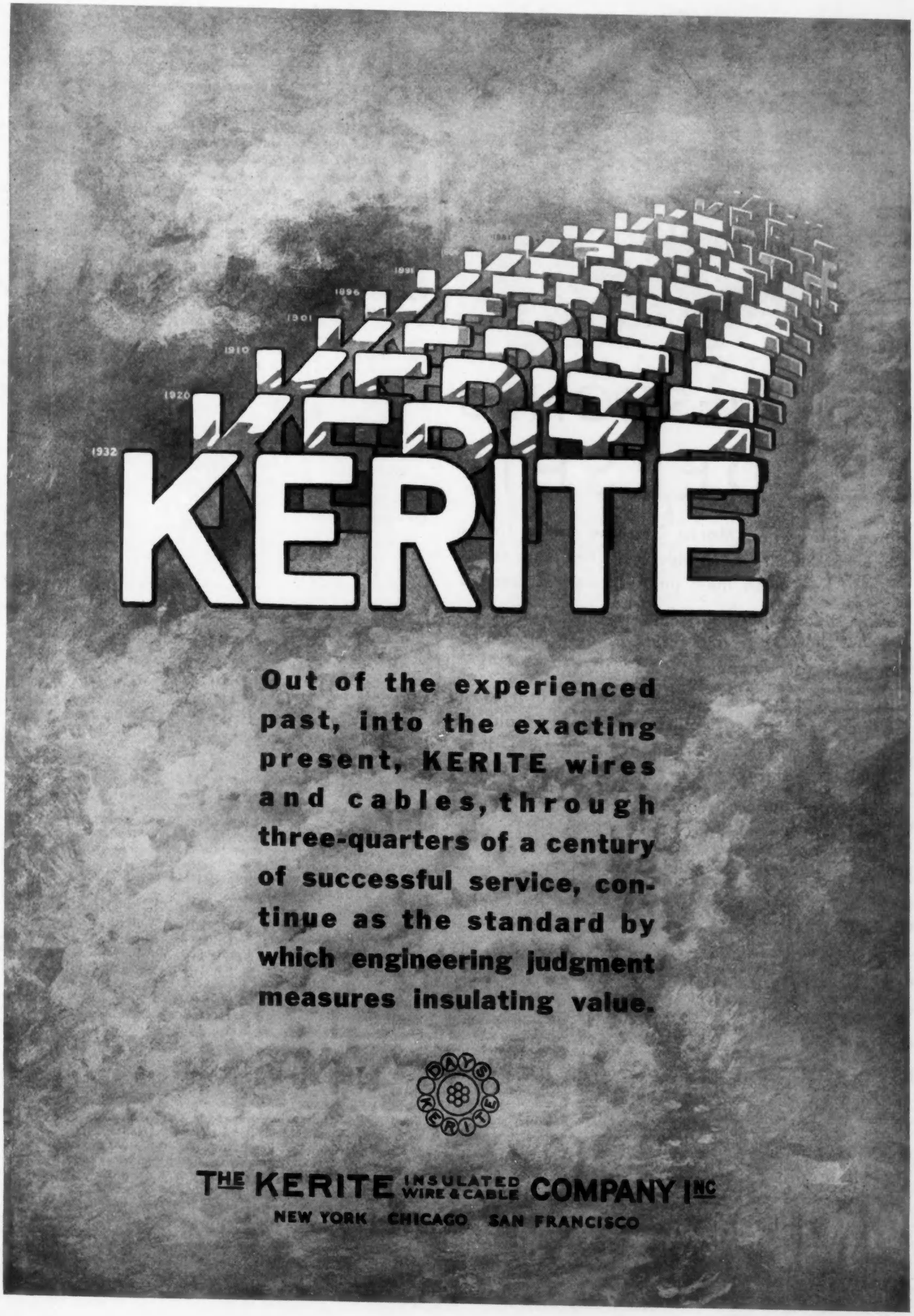
KERITE
Out of the experienced past, into the exacting present, KERITE wires and cables, through three-quarters of a century of successful service, continue as the standard by which engineering judgment measures insulating value.
THE KERITE INSULATED WIRE & CABLE COMPANY INC
NEW YORK CHICAGO SAN FRANCISCO

# *Notes and Reviews*

*Continued*

photograph in a flight series having 60 per cent longitudinal overlap.

**Our National Aviation Program.** By Charles L. Lawrance. Published by the Aeronautical Chamber of Commerce of America, Inc., New York City, 1932, 208 pp. **[A-4]**

In this book, which is compiled from reprints of a series of articles that have appeared in aeronautical trade papers, Mr. Lawrance, president of the Aeronautical Chamber of Commerce of America, Inc., presents analyses of the aviation situation as it confronts us today, not simply as his personal views, but as the accepted policies of the A. C. C. A.

Following are the topics which he covers: The Status of the Aircraft Industry; The Relation of Our Air-Transport System to National Defense; Air Defense from the Viewpoint of the Aircraft Industry; Linking Aircraft Programs to Navy Treaty Strength; Commercial Aviation and National Security; Air Transport as a Market for Aircraft; Development and Cost of the Air Mail Service; The Economic Value of the Air Mail System; The Americas Linked by Air Mail and Transport; Regulation and Aids to Naviagation—Federal and State; Engineering—the Basis of Aviation; Transocean Airship Services and Government Support.

## CHASSIS PARTS

**Uber die Ermittlung der Statischen Biegespannungen in Geschichteten Federn.** By Helmut Stark. Published in *Automobiltechnische Zeitschrift*, Nov. 30, 1931, p. 751. **[C-1]**

The object of the present work is to ascertain the forces on the individual leaves of a leaf spring, when subjected to perpendicular load, by measurement of the leaf deformation, and from this information to draw conclusions as to the bending stress in the individual leaves.

Older methods are criticized on the grounds that they do not consider the spring as subject to an initial tension even when unloaded and that, in other ways, they do not represent true loading conditions. A method of calculation designed to avoid these defects is developed and applied to a symmetrical half-elliptic spring, loaded and unloaded.

## ENGINES

**Optimum Conditions in Journal Bearings.** By Albert Kingsbury. Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York City, Nov. 30 to Dec. 4, 1931. **[E-1]**

In this paper are presented in a practical, serviceable form the more important results obtainable from the hydrodynamic theory of the oil film. The general theoretical treatment is supplemented by numerical evaluations whereby the conditions for maximum load and minimum friction are determined for the ideal bearing; and these results are reduced to apply to practical cases by means of approximate methods. The author gives tables and graphs by means of which the loads, the losses by friction, and other characteristics of specified bearing forms can be determined; and special consideration is given to the optimum conditions for more or less arbitrary bearing proportions.

**Neue Untersuchungen über die Rationalisierung des Kraftstoffverbrauches im Verbrennungsmotor.** Published in *Automobiltechnische Zeitschrift*, Dec. 31, 1931, p. 803. **[E-4]**

In this article on fuel utilization, the author first stresses the necessity for more complete combustion, for both economy and health. He reproduces curves showing the percentage of carbon monoxide, hydrogen and the heavier hydrocarbons in exhaust gas and the variations of these percentages with engine speed. The curves are said to represent the averages obtained from a number of tests in which the fuels used were gasoline, benzol, Motalin, Stellin, Dapolin and Monopolin. About one-half of the heat value of fuel is stated to be lost through incomplete combustion, and the carbon monoxide health hazard is characterized as serious in congested city districts.

Finer fuel atomization and more even distribution of the fuel drops in the fuel-air mixture are thought essential for more complete combustion. An apparatus for the study of fuel-spray atomization and penetration, in which a motion-picture camera is utilized, is described. This test set-up, developed in conjunction with the Berlin engineering college, was designed for the study of fuel injection in Diesel engines but has been adapted to carbureter research. Some microphotographs taken during the course of the research are reproduced.

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# Notes and Reviews

*Continued*

## MATERIAL

**Thermal Expansion of Gasolines from 0 to 30 Deg. Cent.** By C. S. Cragoe and E. E. Hill. Published in the *Bureau of Standards Journal of Research*, December, 1931, p. 1133. **[G-1]**

Measurements are reported on the thermal expansion of 9 straight-run gasolines, 16 cracked gasolines, 3 motor benzols and 5 benzol blends, from 0 to 30 deg. cent. (32 to 86 deg. fahr.). The results indicate that the thermal expansion of cracked gasolines and benzol blends is systematically greater than the values based on straight-run gasolines given in National Standard Petroleum Oil Tables, Bureau of Standards Circular No. 154. The results also indicate that corrections for thermal expansion of present-day motor fuels, including straight-run gasolines, cracked gasolines and benzol blends, can be made more accurately, in general, from a knowledge of their distillation curves than from gravity determinations.

**Influence of Water Composition on Stress Corrosion.** By D. J. McAdam, Jr. Reprint by the American Society for Testing Materials, from the *Proceedings* of that Society, Vol. 31, Part II, 1931. **[G-1]**

Previous reports by Mr. McAdam of the corrosion experiments being conducted at the United States Naval Engineering Experiment Station have been reviewed in these colums from time to time. This reprint from the A.S.T.M. *Proceedings* has recently been made available.

**Thermal Expansion of Heat-Resisting Alloys; Nickel-Chromium, Iron-Chromium and Nickel-Chromium-Iron Alloys.** By Peter Hidnert. Published in the *Bureau of Standards Journal of Research*, December, 1931, p. 1031. **[G-1]**

This paper gives data on the linear thermal expansion of various heat-resisting alloys. The alloys contain 0 to 77 per cent of nickel, 5 to 27 per cent of chromium and 0 to 82 per cent of iron. The coefficients of expansion of the alloys were determined for various temperature ranges between 20 and 1000 deg. cent. (68 and 1832 deg. fahr.) and the effects due to temperature, chemical composition, heat-treatment and the like were ascertained. Critical regions were located on the thermal-expansion curves of some of the alloys.

For a given temperature range, the coefficients of expansion of nickel-chromium alloys containing from 0 to about 20 per cent of chromium are nearly the same.

The effects of chromium content, carbon content and heat-treatment on the coefficients of expansion of iron-chromium alloys for various temperature ranges are indicated in a series of charts.

The results on the thermal expansion of nickel-chromium-iron alloys were correlated with the structure of the alloys. Transformations from one phase to another cause significant changes in thermal expansion. The expansion curves on the first heating of nearly all of the cast nickel-chromium-iron alloys indicate a retardation of decrease in expansion between 700 and 800 deg. cent. (1292 and 1472 deg. fahr.), due to precipitation of carbide. The effects of change of composition on the coefficients of expansion of both cast and annealed nickel-chromium-iron alloys are indicated.

A table in the summary gives a comparison of the coefficients of expansion of the alloys in the three groups.

## PASSENGER-CAR

**Automobile Coatings.** By H. C. Mougey and R. J. Wirshing. Published in *Industrial and Engineering Chemistry*, December, 1931, p. 1352. **[L-1]**

The materials used and typical finishing systems for automobile bodies, fenders, wheels and chassis are described and disadvantages of the present materials and systems are discussed. The following improvements, given in the order of their importance, are desired: rust-resistant fender enamel; lacquer having better chalk-resisting properties; increased resistance to chipping from stones thrown up by tires; a surfacer or surfacing system that will give a surface ready for lacquer or the color coats at lower cost, counting both material and labor; a lacquer or color material or painting system that will give the desired final appearance at lower cost, counting both material and labor; a material or system for producing colored fenders at a cost comparable with that of the present black-enamel fenders; a material or system for finishing chassis at a cost comparable with that obtained at present but possessing much greater resistance to rust and chipping from stones and the like.

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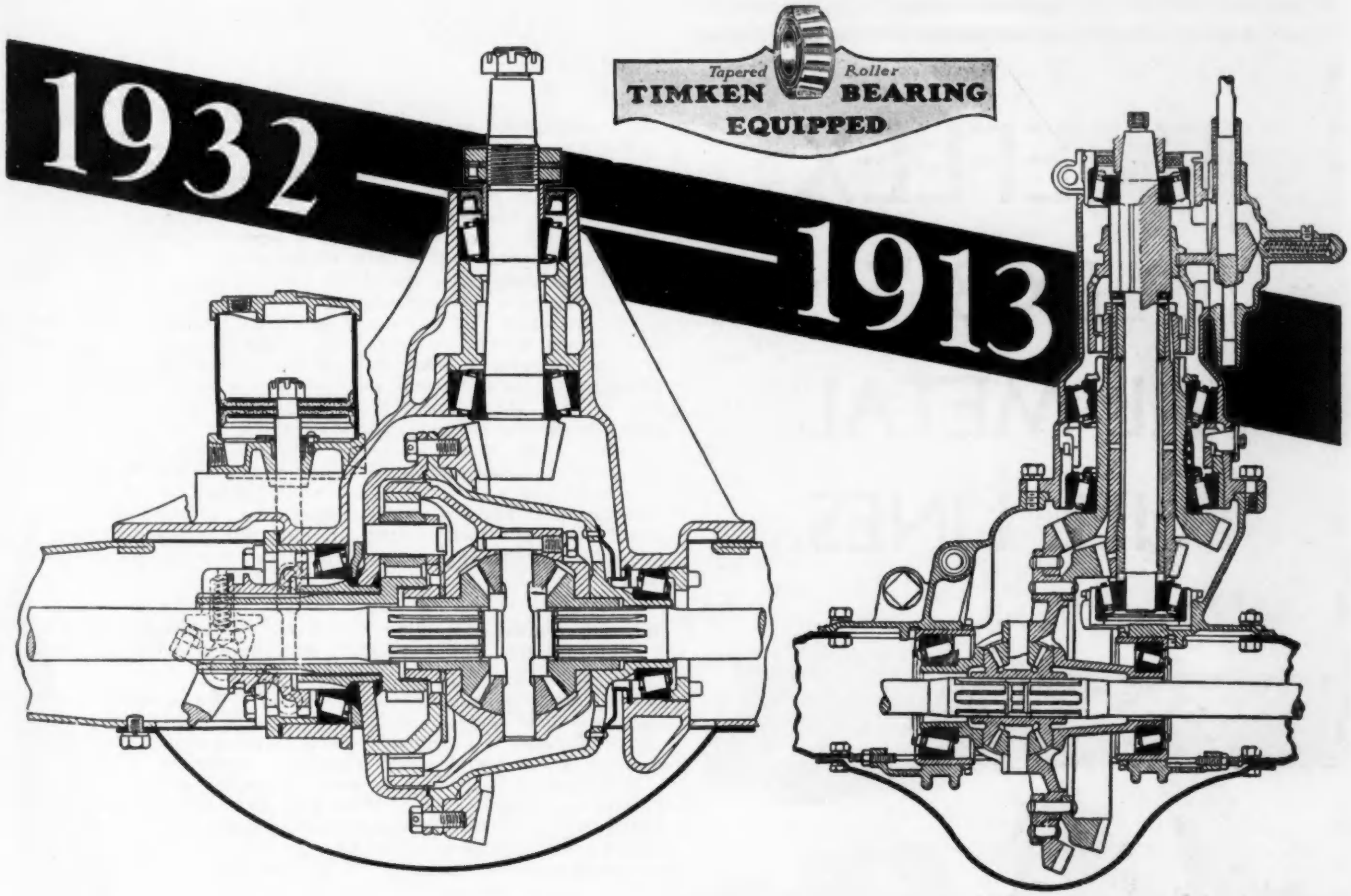



# 19 years apart— but both Timken-equipped

These two-speed rear axles, so radically different in principle, aptly illustrate the progressiveness of automotive engineering thought. It is a tribute to the basic correctness of the Timken Tapered Roller Bearing, however, that nothing completely adequate to take its place has been found—not only during the past 19 years, but for more than 33 years of continuous advancement.

THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO

**TIMKEN *Tapered Roller* BEARINGS**

# Notes and Reviews

*Concluded*

**The Nemesis of American Business.** By Stuart Chase. Published by The Macmillan Co., New York City, 1931; 191 pp. **[H-3]**

Engineers who lack imagination will find much to stir their thoughts in the ten essays in this book by the author of the previous books, Men and Machines and The Tragedy of Waste. Viewing the world of today from the scientist's point of observation, Mr. Chase has put into words most of the half-formed thoughts of many men who decry our present progress. He has dealt with several of the industrial problems and commented scathingly upon the social and municipal results arising from their present partial solution. He pictures the city of the future and speculates upon what changes might improve our lives. He arraigns capital and points out how it has abused its privileges and powers. He discusses mass production, "robot production," and compliments engineers for their ability in lifting the burden from the backs of the workman. He points out the dangers of our present cities and social organizations. He deplores our ignorance, and you will agree with him if you are an engineer. Finally, he makes some suggestions which, if put into practice, would materially improve the situation and incidentally help to eliminate unemployment. The book is well worth a few hours of one's time.

**Automotive Service.** By Ray F. Kuns. Published by the Bruce Publishing Co., New York City, Milwaukee and Chicago, 1931; 1120 pp. **[L-2]**

This volume is an encyclopedic edition of the automotive books written by Mr. Kuns. It is based on an analysis of the automotive trades and is specifically designed as a source of complete training of automotive service men and apprentices.

Each chapter is devoted to some one of the essential units or natural groupings of units. The first part of each chapter is designed to cover the theory of design and the operation of automotive units; the second part is a service department in which have been grouped representative or type jobs.

The book is comprehensive in scope and liberally illustrated with photographs and drawings.

# *Personal Notes of the Members*

(*Concluded from p. 35*)

and assembling for the Whitehead Refrigeration Co., of River Rouge, Mich.

**O. E. Eckert** recently accepted the post of lubrication engineer with the Wilcox Oil & Gas Co., of Tulsa, Okla. He was previously connected with the Empire Refining Co., of Bartlesville, Okla., in the capacity of construction engineer.

**Talbot O. Freeman**, formerly president of the Old Guard Securities Corp., of New York City, is now a principal in the firm of William B. Nichols & Co., also of New York City, engaged in industrial management and financial services.

**The Greenfield Tap & Die Corp.**, of Greenfield, Mass., an Affiliate Member of the Society, recently elected Charles M. Stoddard, formerly general counsel and a director of the Corporation, to the office of president and general manager.

**I. N. Hatch**, who formerly had charge of final production for the Stutz Motor Car Co., of Indianapolis, and later was put in charge of Stutz service in the Chicago territory, has been appointed service manager of the Nash New England Co., of Boston.

**Carl E. Johnson** has been transferred from the position of supervisor of records to that of designer in the household engineering division of the Frigidaire Corp., of Dayton, Ohio.

**Warren P. Loudon** has been appointed assistant general manager of the Pioneer Instrument Co., of Brooklyn, N. Y. His previous connection was with the Delco Aviation Corp., of Dayton, Ohio, of which he was president and general manager.

**H. C. Marble** is now occupying the position of vice-president of the Densol Paint Co., of Independence, Ohio. He previously was vice-president and general manager of the Theatre Garage, in Cleveland.

**Harold L. Pope**, who has been assistant to the president and plant engineer of the Northwestern Leather Co., of Sault Ste. Marie, Mich., now holds the position of plant manager for the company.

**George H. Scragg**, a former executive of Mack Trucks, Inc., of New York City, has accepted an executive position with the Brockway Motor Truck Corp., in the same city.

**E. M. Schultheis**, who for the last five years has been automotive engineer and technical service manager for the Timken Roller Bearing Co., at Canton, Ohio, is now located at the Detroit office and is serving in the same capacity.

**Charles W. Smith** is now employed by the General Aviation Corp., of Baltimore. He was formerly a draftsman with the Olds Motor Works, of Lansing, Mich.

**Henry W. Sweet**, formerly chief engineer of the Krohn Differential Corp., of Buchanan, Mich., is now connected with the Auburn Automobile Co., of Auburn, Ind.

**Norman N. Tilley** has been appointed chief design engineer of the Continental Aircraft Engine Co., of Detroit. His previous position was that of assistant engineer with the American Airplane & Engine Corp., of Farmingdale, N. Y.

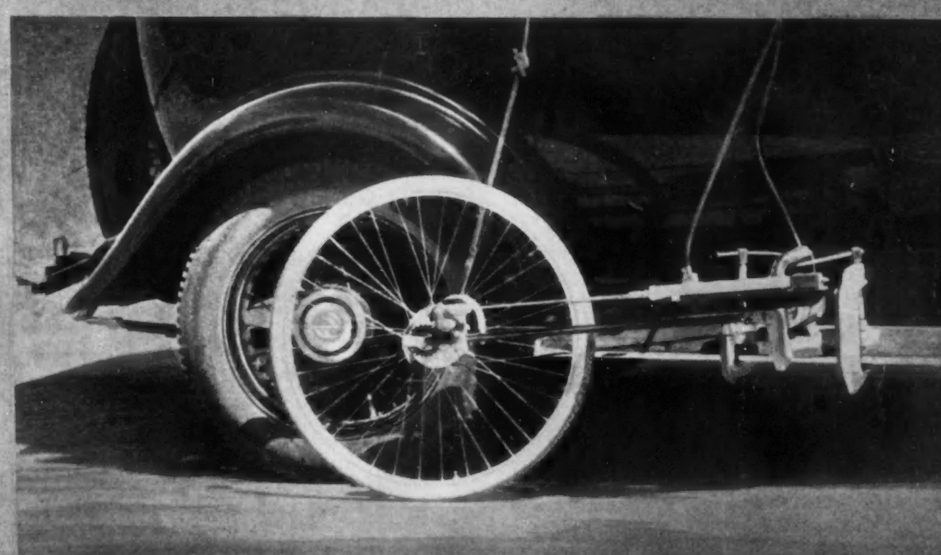
**Edgar L. Vail**, vice-president of the Jaeger Watch Co., Inc., of New York City, sailed for Europe on Feb. 27 to visit London, Paris and Switzerland with reference to the development of new designs for automobile timepieces and mirror-clock combinations.

**Gerald F. Vultee**, who formerly was chief engineer of the Emsco Aircraft Corp., of Downey, Calif., is now serving the Airplane Development Corp., of Burbank, Calif., in the same capacity.

**Cornelius P. Whalen**, having resigned his position as vice-president of Minerva Automobiles, Inc., of New York City, is now engaged in special research engineering work.

**Otto M. Yetter** is now employed as a motorcoach designer by A. M. Wolf, in New York City. He was formerly a junior experimental engineer with the Bijur Lubricating Corp., of Long Island City, N. Y.

# S·A·E JOURNAL



MAY 1932

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